WATER WORKS & SEWERAGE

HBP ABC

180 LARGE CHAPMAN VALVES

for

Chicago's New Filtration Plant

Here in the Chapman plant, ready to undergo searching hydrostatic tests, are a few of the eighty 42″ Chapman Iron Body Gate Valves built for the new South Side Filtration Plant of the City of Chicago. For this great modern plant, subject to the most intensive operating requirements, Chapman supplied a total of 180 Iron Body Gate Valves, in sizes from 36″ to 54″.

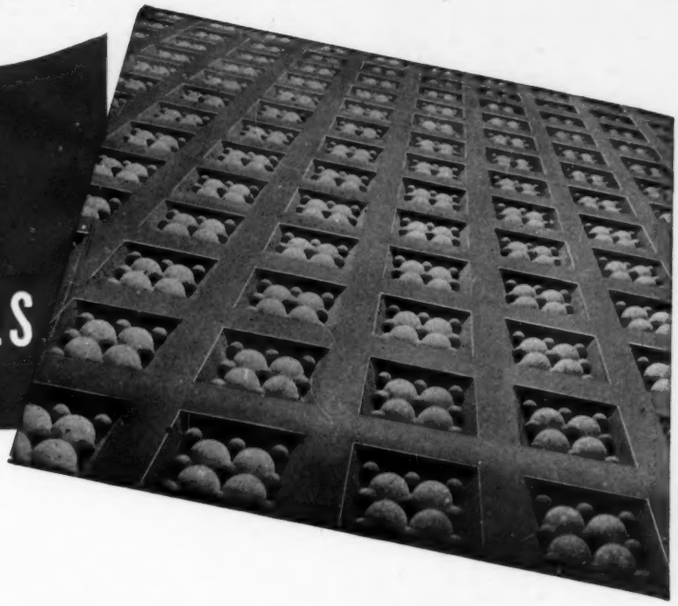
And every one of these Chapman Valves can be depended upon to give uniformly dependable service throughout long years to come . . . to do their part to uphold the City's high standards of public utility service . . . and to hold down the long-term public investment in equipment of this type.

COMPLETE CHAPMAN LINE-UP
in the new Chicago Filtration Plant

80 — 42″ Iron body valves, cylinder operated. Installed on wash water drain lines
80 — 30″ ditto — used as influent valves
4 — 42″ and 4 — 54″ Iron body motor operated gate valves used as pump suction valves
8 — 36″ and 8 — 48″ Iron body motor operated gate valves
4 — 36″ and 4 — 48″ Automatic Cone Check Valves
These were used as pump discharge valves

The **CHAPMAN VALVE MANUFACTURING CO.**, Indian Orchard, Massachusetts

...-Save
CRITICAL MATERIALS



specify

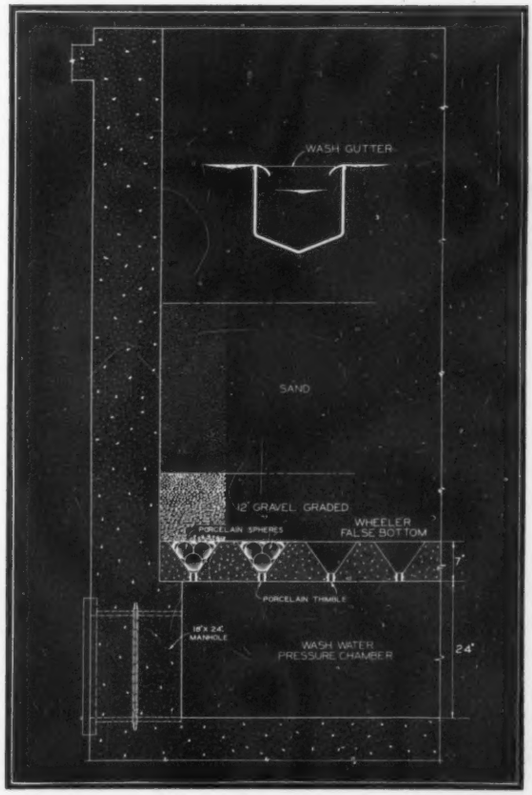
The WHEELER FALSE FILTER BOTTOM

Requires less than four pounds of metal (reinforcing steel) per square foot of area. Otherwise constructed only of concrete and porcelain throughout.

In most cases of substitution for critical materials some sacrifice must be made in efficiency or durability. Here, however, the Engineer may avoid critical metal and, at the same time, enhance both the efficiency and durability of the whole underdrainage system. No more efficient or more durable filter underdrainage system than the Wheeler False Filter Bottom has yet been devised.

Already we have completed, or have under contract, twenty-five installations of Wheeler False Filter Bottoms in plants directly associated with the war effort. The combined daily capacity of these installations is 225,000,000 gallons. The smallest has a rated capacity of 150,000 gallons per day, and the largest 36,000,000 gallons per day.

Write us for technical information



MECHANICAL EQUIPMENT
BY
ROBERTS FILTER MFG. CO.
607 COLUMBIA AVE.
DARBY, PENNA.

This name plate is our pledge of cooperation—of adherence to specifications—of quality of materials —of excellence of workmanship—of continuing interest long after the contract price has been paid.

Announcing . . .

A FULLY PROTECTED IRON CASE WATER METER with V-Glass Register Box

As the meter reader sees it—the V-Glass Register Box provides clear vision for quick, accurate meter reading and tightly seals the register mechanism against dust and moisture.

THE Empire Victory Meter is a fully protected iron case meter having a molded glass register cover. About 70% of the bronze normally used in a meter of this size has been eliminated without sacrificing any of the quality construction details that have, for 72 years, been associated with the Empire name. The time tested oscillating piston principle of measurement, using the famous Empire Balanced Piston, provides unexcelled accuracy. Smooth flow lines and interior contours, in combination with a measuring chamber having dual inlet and outlet ports, keeps pressure absorption at the absolute minimum. The design incorporates many innovations in construction that reduce friction and wear, assuring retention of the high initial accuracy of the meter over a long period of time. The Empire Victory is a meter that will give thoroughly dependable, unfailingly accurate service both for the duration and for many years to come. Descriptive literature will be sent upon request.

Plan Now to Attend the American Water Works Association Conference on Wartime Water Works Problems, The Stevens Hotel . . . Chicago, Ill . . . June 21-25, 1942

Another Development from **PITTSBURGH-NATIONAL** *Research Laboratories*

THE Empire VICTORY Mete

TRIPLE PROTECTION FOR CAST IRON CASE—Triple protection is given to the cast iron case of the Victory Meter. All machined surfaces are chemically treated to inhibit the formation of corrosion.

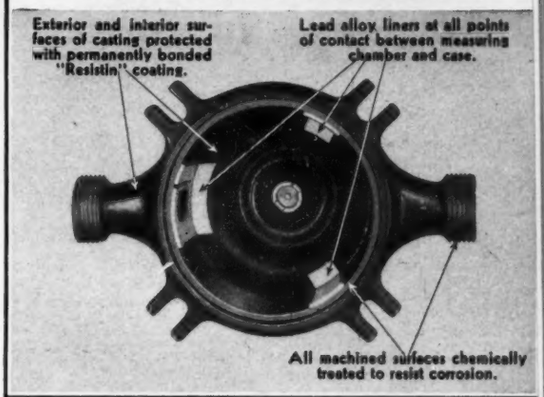
The casting surfaces are protected with a special coating called "Resistin". This coating has been *field proven* for several years on thousands of frost model Empire Meters, where cast iron bottom plates have been so protected. "Resistin" is a special synthetic resin enamel finish, baked at elevated temperature. It is permanently bonded to the metal on both interior and exterior of the meter case.

The interior of the main casing in the Empire Victory Meter is lined with a special lead alloy at all points where the measuring chamber comes in contact. (Patent applied for.) This lining provides a perfect jointing surface between these parts and prevents the formation of corrosion which would make removal of the measuring chamber difficult.

V-GLASS REGISTER BOX—The "crown" of the Victory Meter is the V-Glass Register Box. Conventional meter construction in the past has included a register box and lid made from bronze. These parts are not under pressure and serve only to encase the register and exclude dirt and moisture. They compare to the housings for electric meters which for years have been molded from glass. Taking a tip from the electric meter manufacturers, Pittsburgh-National engineers have designed the V-Glass Register Box. This is a single piece, strong, molded glass unit which fits snugly over the register and is retained by two screws against a fibre gasket. The V-Glass Register Box serves as both a register box and lid. It tightly seals the register against dust and moisture and will withstand considerable abuse.

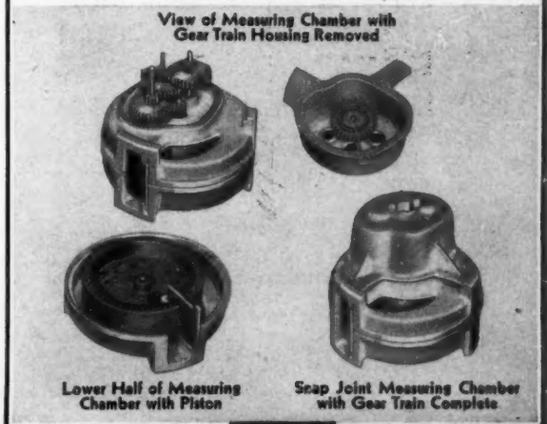
THE FAMOUS EMPIRE OSCILLATING PISTON DESIGN—There is but one moving part within the snap-joint type measuring chamber—the famous Empire balanced piston with centrally located web. This scientifically designed and proportioned chamber extracts the ultimate in sustained accuracy from the balanced oscillating piston. There are only three interior bronze castings. The four-wheel, oil enclosed gear train, utilizes the top half of the measuring chamber as the gear train bottom plate. This assures absolute alignment between the measuring chamber and the driving arm of the intermediate train. The design eliminates all need for interior screws and makes possible the assembly of all working parts as a complete unit before installation in the meter case.

TRIPLE PROTECTION FOR CAST IRON CASE


Exterior and interior surfaces of casting protected with permanently bonded "Resistin" coating.
Lead alloy liners at all points of contact between measuring chamber and case.
All machined surfaces chemically treated to resist corrosion.

V-GLASS REGISTER BOX

THE FAMOUS EMPIRE OSCILLATING PISTON DESIGN


View of Measuring Chamber with Gear Train Housing Removed
Lower Half of Measuring Chamber with Piston
Snap Joint Measuring Chamber with Gear Train Complete

PITTSBURGH - NATIONAL METERS

THE MOST COMPLETE LINE OF WATER METERS IN THE WORLD

PITTSBURGH EQUITABLE METER COMPANY

NEW YORK · BROOKLYN · DES MOINES · MEMPHIS · OAKLAND · TULSA · CHICAGO · BOSTON

MERCO NORDSTROM VALVE COMPANY
Main Offices, Pittsburgh, Pa.

KANSAS CITY · PHILADELPHIA · SAN FRANCISCO · SEATTLE · HOUSTON · COLUMBIA

NATIONAL METER DIVISION Brooklyn, N. Y.

IMAGINEERING: GETTING OUT OF THE GROOVE

THESE FOUR YOUNG WOMEN, so earnestly mastering the art of torch-welding aluminum, suggest that someone, somewhere, has checked out of the groove and started some practical Imagineering.

THEY PROVE what we've been saying for years: Alcoa Aluminum is easy to fabricate. The man who started the school where these girls are learning, and graduating to war jobs, simply had imagination enough to believe that

easy really means *easy*. Then he did something about it!

IMAGINEERING is letting your imagination soar and then engineering it down to earth. It is ingenuity in modern dress.

IT IS THE THING that has enabled the aluminum industry to keep on top of a plane schedule, increased tremendously in numbers, but also calling for almost twice as much aluminum per plane as the average plane needed two years ago.

IT IS WHAT EVERY ONE OF YOU are doing on your war job. Simplification, standardization, training. New methods, new materials, new records.

THIS WAR is showing Americans what they really can do if they try.

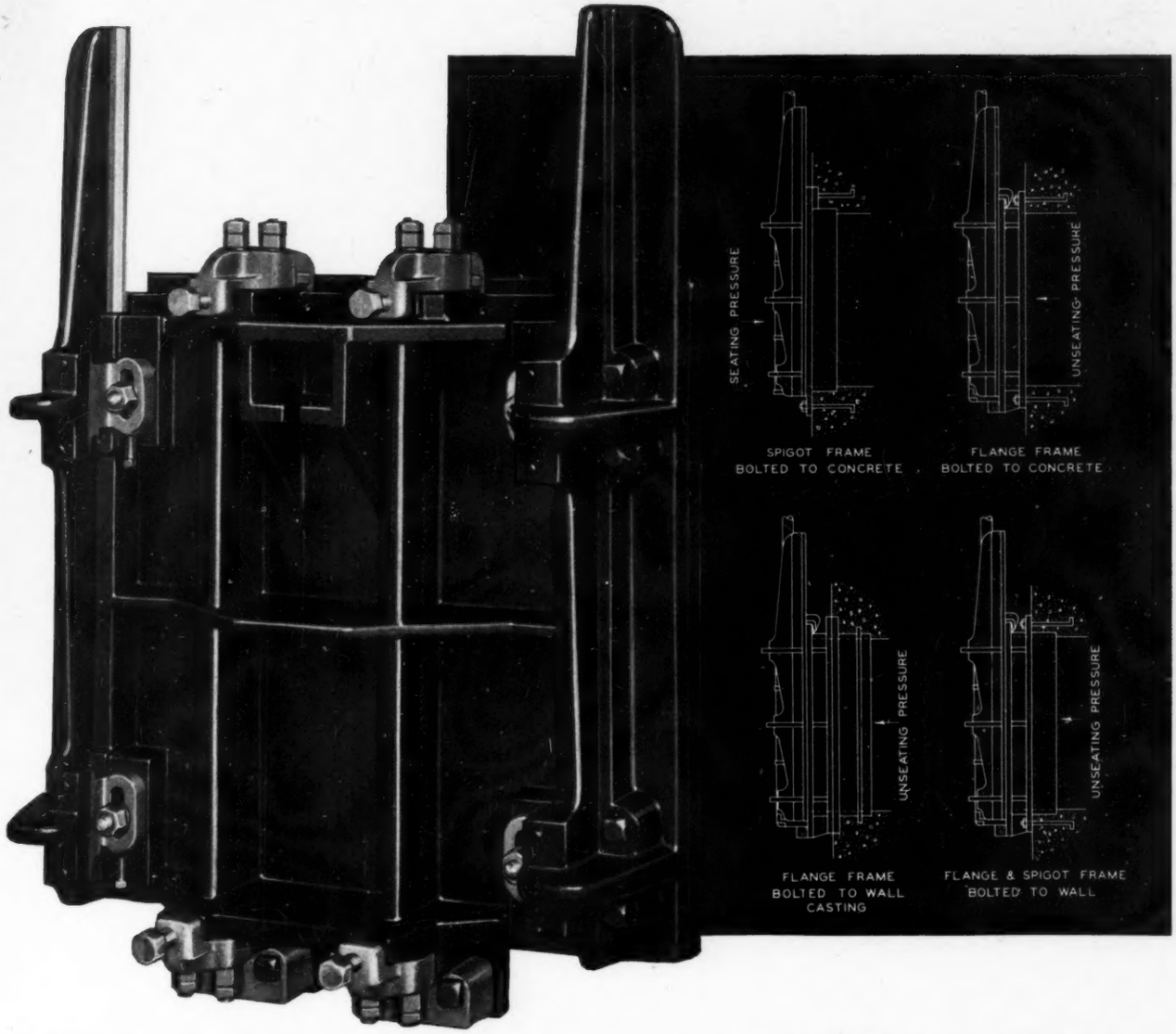
LET'S MAKE a vow to carry this same spirit over into postwar America. We'll all have the skills, the habit of work, the thrill of doing. There will be lots of aluminum to make into better products than peacetime America ever knew. It will be a great day for Imagineers.

Aluminum Company of America, 1955 Gulf Building, Pittsburgh, Pennsylvania.

★ SO MUCH SO SOON ★

ALCOA ALUMINUM

WATER WORKS & SEWERAGE, June, 1942. Volume 89. Number 6. Published monthly by Gillette Publishing Co., 330 South Wells Street, Chicago, Ill. Per copy, 50c. Subscription rate, United States, $2.00 per year; Canada, $2.00 per year; Foreign, $3.00 per year. Entered as Second Class Matter, June 2, 1931, at the Post Office at Chicago, Ill., under Act of March 3, 1879.



SMOOTH-AS-VELVET OPERATION

NATIONAL GATE VALVES

You can specify National Gate Valves for Water Works operation with full assurance that their time-tested designs and husky construction will operate with fool-proof dependability. The National line of Water Works Specialties is complete . . . special designs developed promptly by our engineering staff.

A glance at this National Sluice Gate will show you that it is built to operate smoothly and easily against any usual pressure head. And that ample sizing of all parts provides a construction sturdy enough to give long-term service.

Frames, discs and guides are a fine grade of semi-steel, with frames cast in one piece and discs heavily ribbed for greatest strength. All wedges and hooks are of Manganese Bronze.

National Sluice Gates are distinguished by the careful machining and fitting of all sliding and screw parts. The facings on the frames and discs are made of a special-analysis bronze, found most suitable for the required service, and thoroughly peened into machined, dove-tailed grooves. These Gates are *water-tight* and open and close easily without chattering.

National Sluice Gates may be operated with hand or electric operated floor stands, or with hydraulic cylinders. They are offered in both rising stem and non-rising stem types. Send today for descriptive literature.

SEND FOR LITERATURE

NATIONAL

MACHINE WORKS

1559 N. Sheffield Ave., Chicago, Ill..

ESTIMATES CHEERFULLY GIVEN

NORIT

The Economical Activated Carbon for Purifying Water Supplies

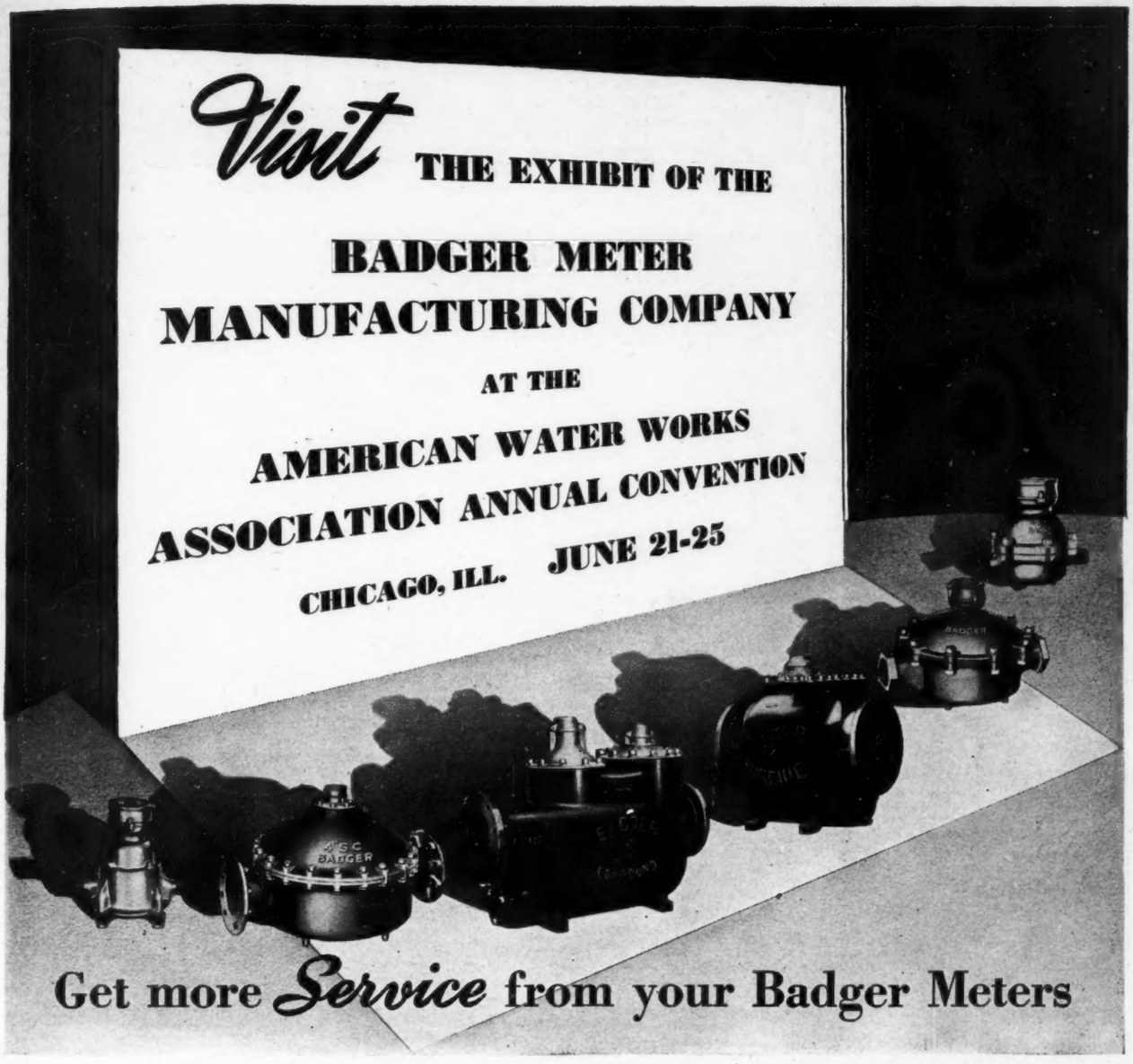
NORIT is made by the steam activation process, using purest wood charcoal as raw material. No chemicals are used. Guaranteed phenol value in powdered form is 14 or better. Guaranteed phenol number in granular form is not less than 9.

Produced by

AMERICAN NORIT COMPANY, INC.

Jacksonville, Florida

Distributed by **L. A. SALOMON & BRO., 216 Pearl Street, New York, N. Y.**



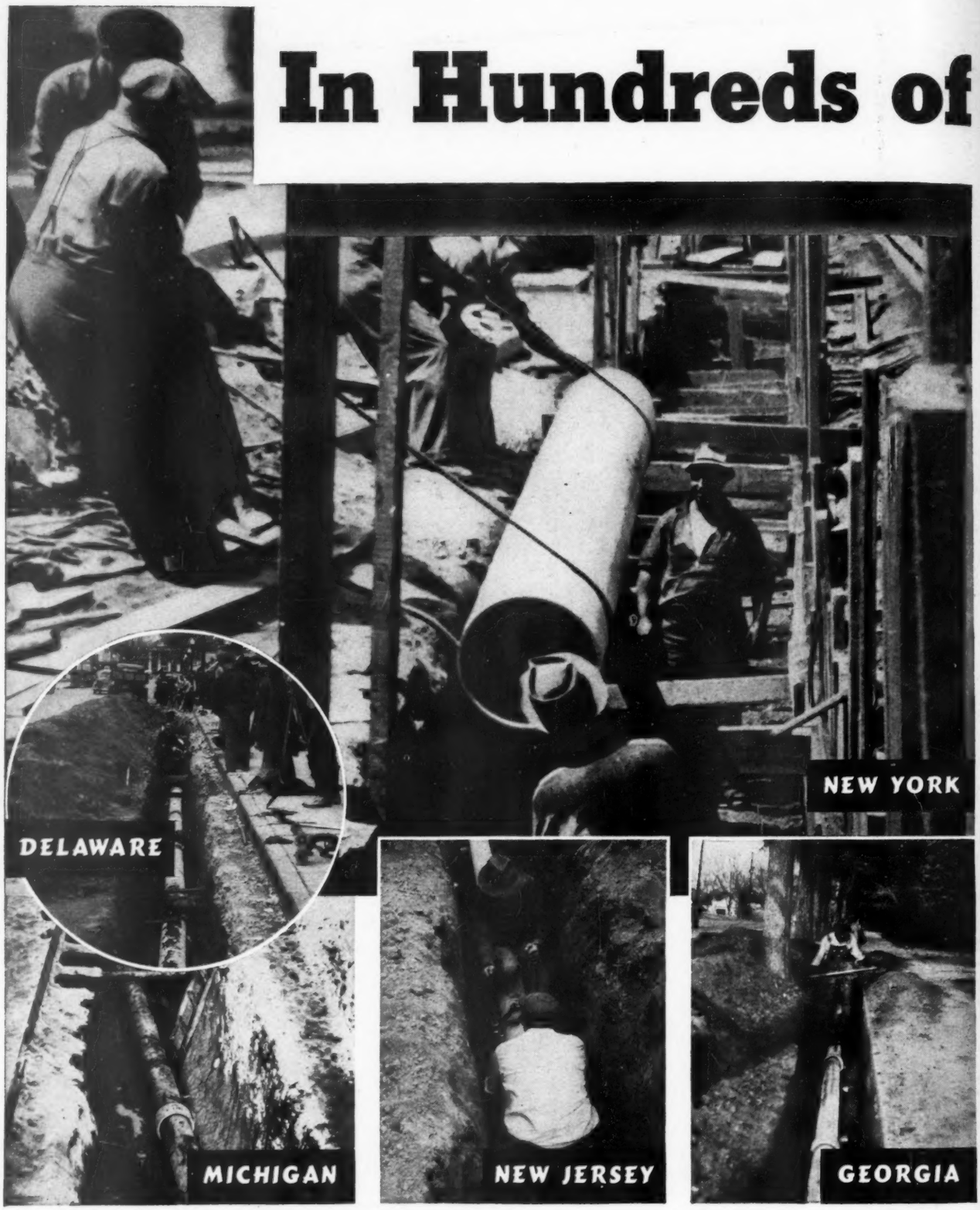
Careful maintenance of water meters—insuring accuracy and long life, is essential to revenue protection and reduction of waste at all times. In these emergency times keeping meters in good operating condition is vital. Patriotism demands conservation of water and conservation of present equipment — guarding against future uncertainties regarding replacements.

Badger water meters—ranging from the ⅝" disc to 10" compounds and 12" turbines—feature simplicity of design, which assures easy interchange of parts—economical repair, low maintenance expense. Badger Meter's national reputation for Durability, Dependability, Sensitivity and Low-Cost Maintenance has been earned by 32 years of performance under all types of severe service conditions. Consult us at our Convention booth for practical assistance in water meter repair, maintenance and replacement.

BADGER METER MANUFACTURING CO.
MILWAUKEE, WISCONSIN

BRANCH OFFICES: New York City • Tampa, Fla. • Seattle, Wash. Savannah, Ga. • Kansas City, Mo. • Marshalltown, Iowa • Waco, Texas Los Angeles, Calif. • Chicago, Ill. • Philadelphia, Pa.

In Hundreds of



JOHNS-MANVILLE PRODUCTS

Johns-Manville

An Asbestos Product . . . *For efficient,*

Communities

from coast to coast, efficient, economical water transportation is assured by the use of J-M Transite Pipe. Check the advantages of this modern water carrier . . .

No Tuberculation . . . Transite has an initial flow coefficient of C=140. This can never be reduced by tuberculation because Transite is made of asbestos and cement, non-metallic.

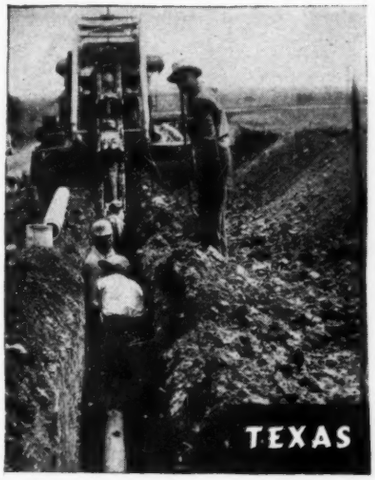
Low Maintenance . . . Transite's asbestos-cement composition provides the further advantage of high corrosion-resistance, thus reducing maintenance.

Minimum Leakage . . . for the Simplex Coupling used in assembling Transite stays tight in service . . . is so flexible that movement of as much as 5° is allowed at joints. This flexibility also permits straight lengths of pipe to be used on wide sweeps.

Rapid Assembly . . . While the Simplex Coupling forms lasting tight joints, it is so easy to assemble that unskilled crews can be used on any job. It is prefabricated, a "packaged" joint that eliminates heating or pouring operations.

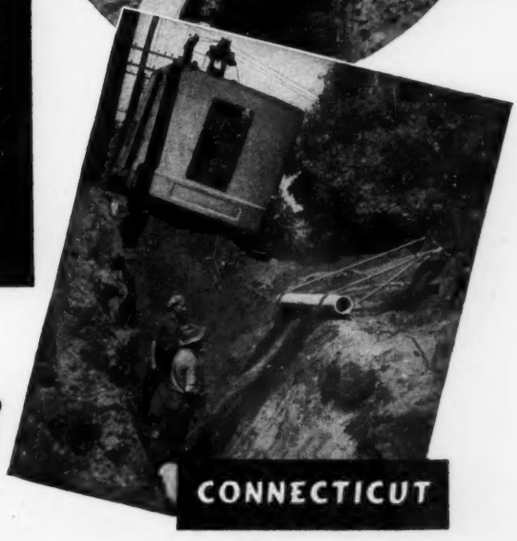
Easy Handling . . . the result of Transite's light weight. Mechanical equipment for unloading and lowering is required only on the largest sizes.

For complete details, write for brochure TR-11A. And for information on the use of Transite Sewer Pipe to reduce sewage disposal costs, write for brochure TR-21A. Johns-Manville, 22 East 40th Street, New York, N. Y.



BE SURE TO ATTEND

the A. W. W. A. Conference on Wartime Water Works Problems, Chicago, June 21st to 25th. You are cordially invited to visit the J-M Exhibit, Booths 50 to 53.



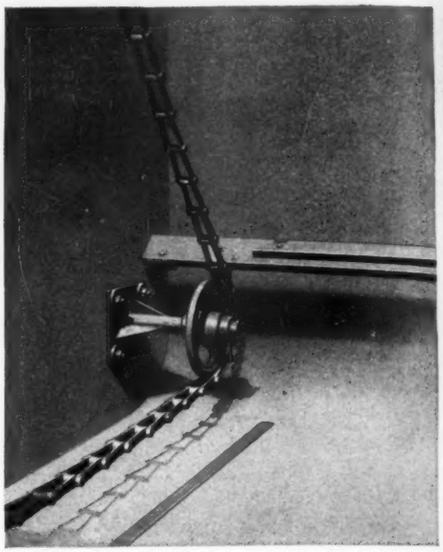
TRANSITE PIPE

economical water and sewer lines

"American" COLLECTORS

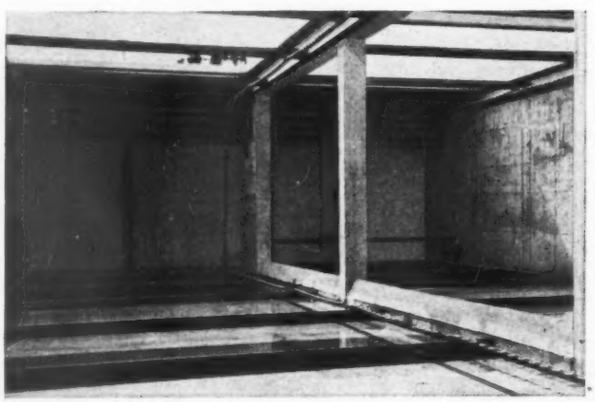
featuring

CANTELEVER IDLERS



★

- Bearing inside hub and rotating around shaft.
- Easily installed and aligned sprocket assembly.
- Elimination of spring and catenary, common to old style long cross shafts.
- Solid support for idler sprockets.
- Increased rigidity over other types.
- Elimination of undesirable heavy steel cross shafting.

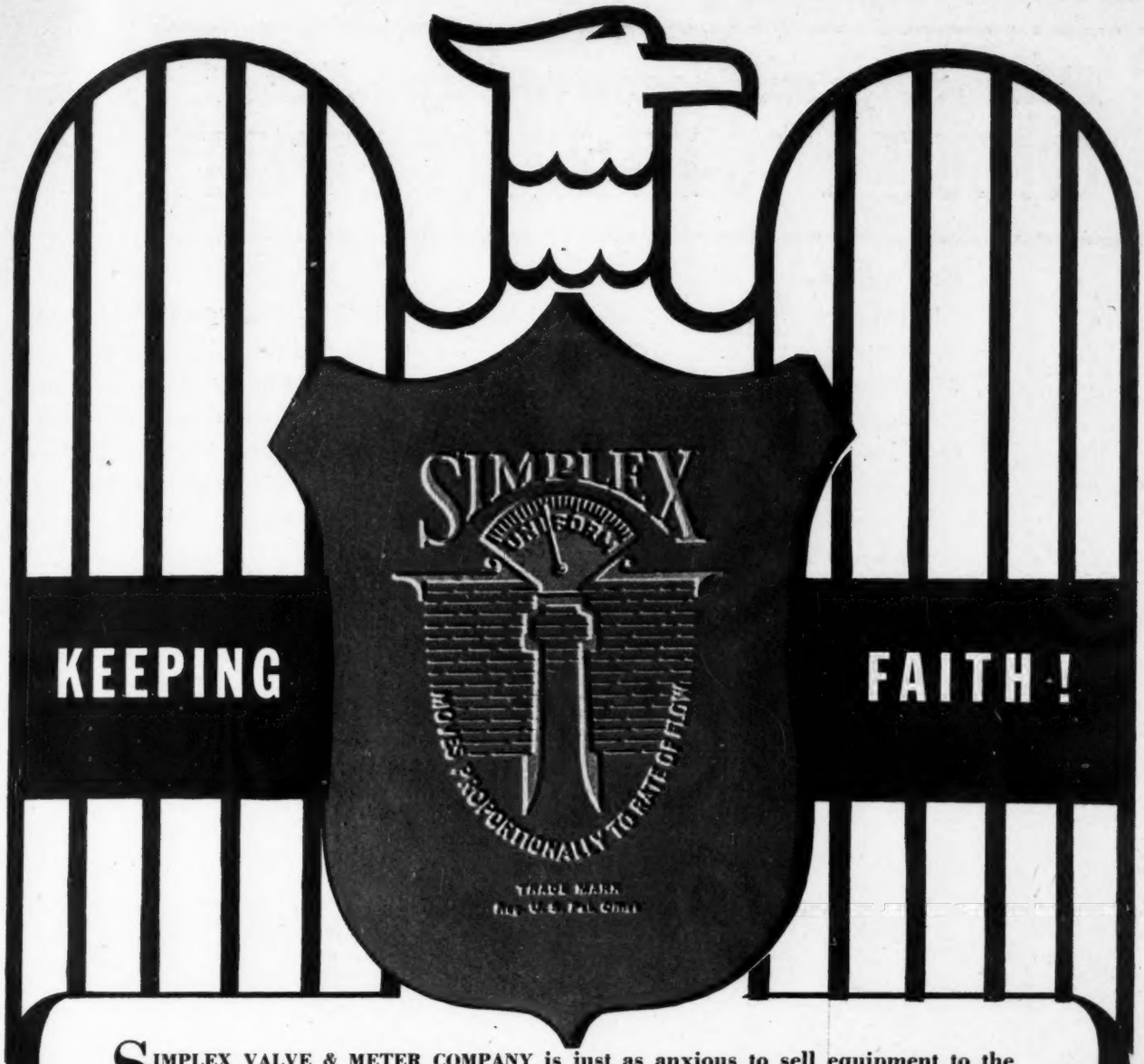


TORQUE TUBE HEAD SHAFT

- Section modulus increased over solid steel head shaft with less overall weight.
- Wider tanks can be used.

★

Installation at
Rocky Mount, No. Carolina
By J. E. SIRRINE & CO., Engineers



SIMPLEX VALVE & METER COMPANY is just as anxious to sell equipment to the Water Works and Sewage Plant as anyone in the industry; so don't take what follows as a sign that we do not want nor cannot take care of your business.

However, in the interests of our common war effort, Simplex urges you to take stock of the meters, controllers, gauges, and other equipment in your plant. Check them for accuracy, wear, and damage. If they are not operating 100% efficiently, have them reconditioned and put back into service.

As we see it, this is no time for slipshod methods. We're all in the same boat—only so much raw material is available for Water Works and Sewage use, and every manufacturer of equipment, and every user of this equipment has practically the same priority rating for this new material. So it seems to us a wise plan to get "more miles from your meters" for many tomorrows, because we've all taken care of them today.

The inherent value of such a plan is self evident. Simplex Valve & Meter Company has set up a special maintenance department to service Simplex equipment quickly and well. Fortunately none of us are forced to do these things. Let's keep it that way by doing them of our own free will.

SIMPLEX VALVE & METER CO., 6743 UPLAND ST., PHILADELPHIA, PA.

Visit us at the A.W.W.A. Conference in Chicago, June 20-25th. Talk with Simplex service engineers who will be glad to advise you on the care of Simplex meters.

Planning a Pressure Pipe Line?
CONSULT A CO-EFFICIENCY EXPERT

He'll tell you:

"To maintain a permanently high carrying capacity your best pipe line investment lies in concrete."

And your first choice would naturally be Lock Joint Reinforced Concrete Pipe. Its dense, concrete walls form an unrelentingly smooth line of defense against Tuberculation and Corrosion, the aggressive surface diseases that with time attack and cripple most water supply lines. Tuberculation and Corrosion cannot leave their mark on Lock Joint's moulded concrete, cannot impair the hydraulic efficiency of these pipes.

Lock Joint Pipe does maintain a high carrying capacity for life but its very construction and design insure longer life, longer serviceability. Encased within the protective coat of concrete lies a water-tight steel cylinder, reinforced by encircling steel bars. This is the backbone, these are the ribs that enable each Lock Joint Pipe to withstand indefinitely the forces of pressure, weight and shock. A more useful life—and a longer one!

Whether your project is large or small, your 'phone call, telegram, cable or letter to any of our offices will bring an immediate response.

LOCK JOINT PIPE COMPANY

Established 1905

AMPERE, NEW JERSEY

Denver, Colo. • Chicago, Ill. • Kenilworth, N. J. • Kansas City, Mo. • Rock Island, Ill.
White Plains, N. Y. • Valley Park, Mo. • Cleveland, Ohio • Hartford, Conn. • Navarre, Ohio

SCOPE OF SERVICES

Lock Joint Pipe Company specializes in the manufacture and installation of Reinforced Concrete Pressure Pipe for Water Supply Mains as well as Concrete Pipe of all types for Sanitary Sewers, Storm Drains, Culverts and Subaqueous lines.

LOCK JOINT
Reinforced Concrete
PRESSURE PIPE

STANDARD
SILICATE OF SODA

and gain these "plus" values . . .

★ IMPROVED FLOCCULATION
★ INCREASED FILTER RUNS
★ REDUCED COSTS

ALKALI

● From coast to coast, water softening plants are using STANDARD SILICATE to stop the costly attacks of corrosion—and gaining thereby many additional benefits—more effective treatment, lower costs, dependably uniform results.

Our Technical Staff will gladly give you the benefit of their research and findings in the use of Silicates of Soda for water treatment. Just fill in the coupon and drop it in the mail.

DIAMOND ALKALI COMPANY
STANDARD SILICATE DIVISION
PITTSBURGH, PA.

Plants at CINCINNATI · JERSEY CITY · LOCKPORT, N. Y.
MARSEILLES, ILL. · DALLAS, TEXAS

Standard Silicate Division, Diamond Alkali Company,
Oliver Building, Pittsburgh, Pa.
Our water supply has the following characteristics:
.....Million Gallons per Day Average Turbidity.....
Present Dosage.....gr./gal. Coagulant.....
We would be glad to receive further information on the use of Standard Silicate.
Name.....*Title*.....
Water Works.....*City*.....*State*.....

Planning a Pressure Pipe Line?
CONSULT A CO-EFFICIENCY EXPERT

He'll tell you:

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White Plains, N. Y. • Valley Park, Mo. • Cleveland, Ohio • Hartford, Conn. • Navarre, Ohio

LOCK JOINT
Reinforced Concrete
PRESSURE PIPE

SCOPE OF SERVICES — *Lock Joint Pipe Company specializes in the manufacture and installation of Reinforced Concrete Pressure Pipe for Water Supply Mains as well as Concrete Pipe of all types for Sanitary Sewers, Storm Drains, Culverts and Subaqueous lines.*

STANDARD
SILICATE OF SODA

and gain these "plus" values . . .

★ IMPROVED FLOCCULATION

★ INCREASED FILTER RUNS

★ REDUCED COSTS

ALKALI

● From coast to coast, water softening plants are using STANDARD SILICATE to stop the costly attacks of corrosion—and gaining thereby many additional benefits—more effective treatment, lower costs, dependably uniform results.

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DIAMOND ALKALI COMPANY
STANDARD SILICATE DIVISION
PITTSBURGH, PA.

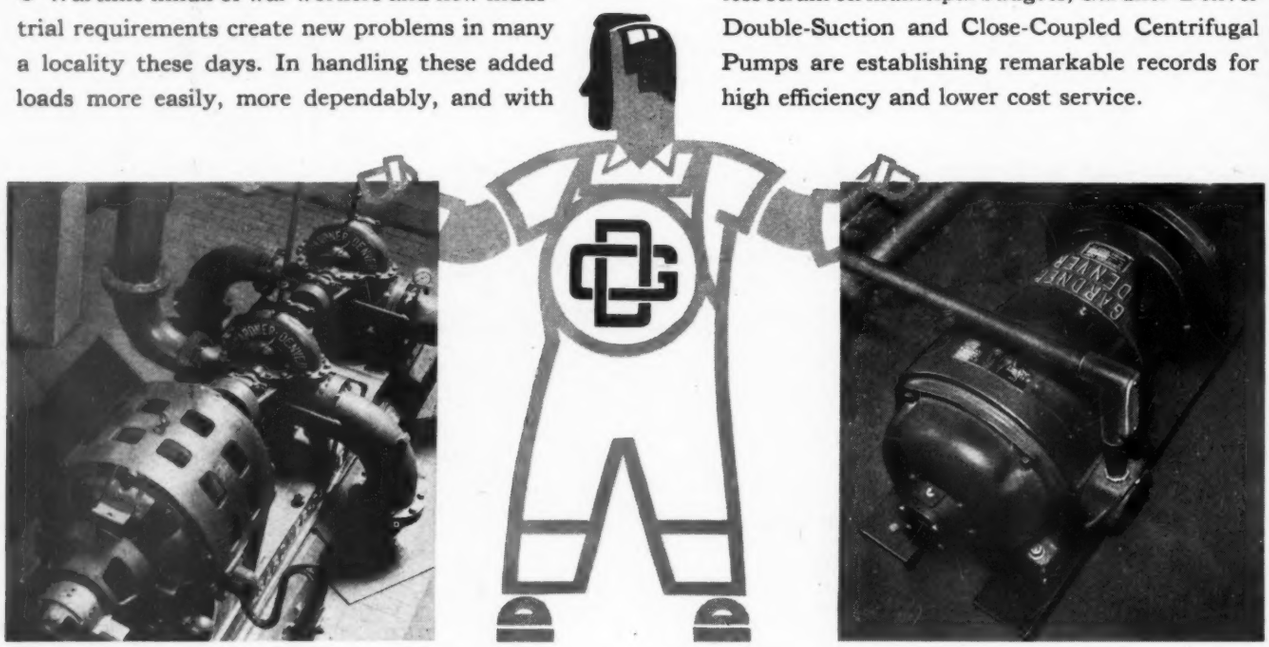
Plants at CINCINNATI · JERSEY CITY · LOCKPORT, N. Y.
MARSEILLES, ILL. · DALLAS, TEXAS

Standard Silicate Division, Diamond Alkali Company,
Oliver Building, Pittsburgh, Pa.
Our water supply has the following characteristics:

.....Million Gallons per Day Average Turbidity.....
Present Dosage.....gr./gal. Coagulant.....
We would be glad to receive further information on the use of Standard Silicate.
Name.....*Title*.....
Water Works.....*City*.....*State*.....

Easier Handling FOR THAT ADDED LOAD

● Wartime influx of war workers and new industrial requirements create new problems in many a locality these days. In handling these added loads more easily, more dependably, and with less strain on municipal budgets, Gardner-Denver Double-Suction and Close-Coupled Centrifugal Pumps are establishing remarkable records for high efficiency and lower cost service.



● The extra performance of Gardner-Denver Double-Suction, Horizontally Split Case Centrifugal Pumps is assured by large, smooth waterways that prevent eddies and cross currents—cast bronze, enclosed type, hydraulically balanced impeller plus heavy-duty, single row ball bearings that absorb line and thrust loads. These rugged Gardner-Denver pumps are designed for heads up to 350 feet.

● The efficient operation of Gardner-Denver Type "H" Close-Coupled Centrifugals is the result of carefully proportioned and thoroughly tested water passages and impeller blades. Pump and splashproof motor form a compact unit, and can be installed in any position, horizontally or vertically. Designed for capacities up to 250 gallons per minute and heads up to 300 feet.

GARDNER-DENVER PRODUCTS HELP SPEED VICTORY

Write for full information on the improved mechanical advantages and modern hydraulic design of Gardner-Denver Double-Suction and Close-Coupled Centrifugal Pumps. Gardner-Denver Company, Quincy, Illinois.

GARDNER-DENVER *Since 1859*

KEEP 'EM FLYING!

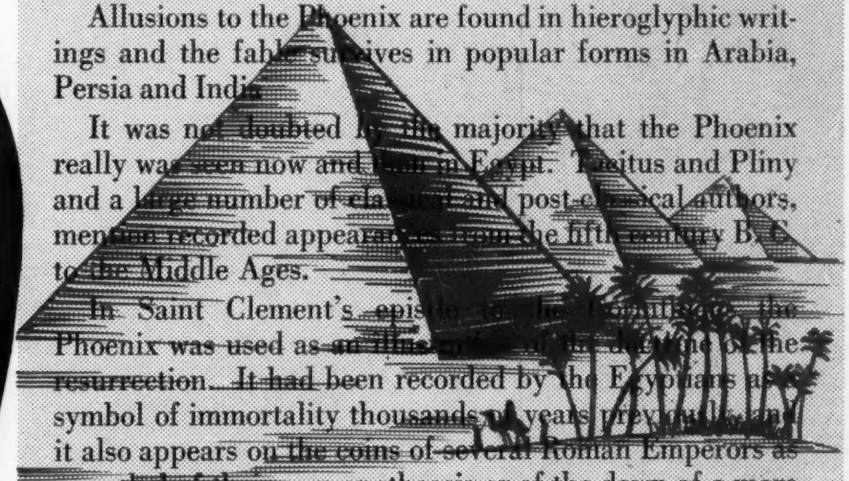
Our Phoenix Emblem

THE PHOENIX was a fabulous sacred bird of the Egyptians, about the size of an eagle, with gorgeous red and golden plumage and, according to one or two authorities, possessing a sweet voice. It was always male, the only one of its kind in the world, and lived in the Arabian wilderness for periods ranging from five hundred years upward.

At the expiration of that time, when it felt its life drawing to a close, it built itself a nest of twigs from spice trees and aromatic gums, on which it died, by setting the nest on fire with the fanning of its wings, and burning itself alive. From its body, or its ashes, or the nest which it had fertilized, came forth another Phoenix, beautiful and revived with the freshness of youth. This young bird, as soon as it was strong enough, took up the body of its father, covered in spices, or the ashes, nest and all, and flew to a sanctuary dedicated to it at Heliopolis in Egypt, where it deposited them on the altar of the Sun.

By heralds the Phoenix is always presented in the midst of flames.

Allusions to the Phoenix are found in hieroglyphic writings and the fable survives in popular forms in Arabia, Persia and India.



It was not doubted by the majority that the Phoenix really was seen now and then in Egypt. Tacitus and Pliny and a large number of classical and post-classical authors, mention recorded appearances from the fifth century B. C. to the Middle Ages.

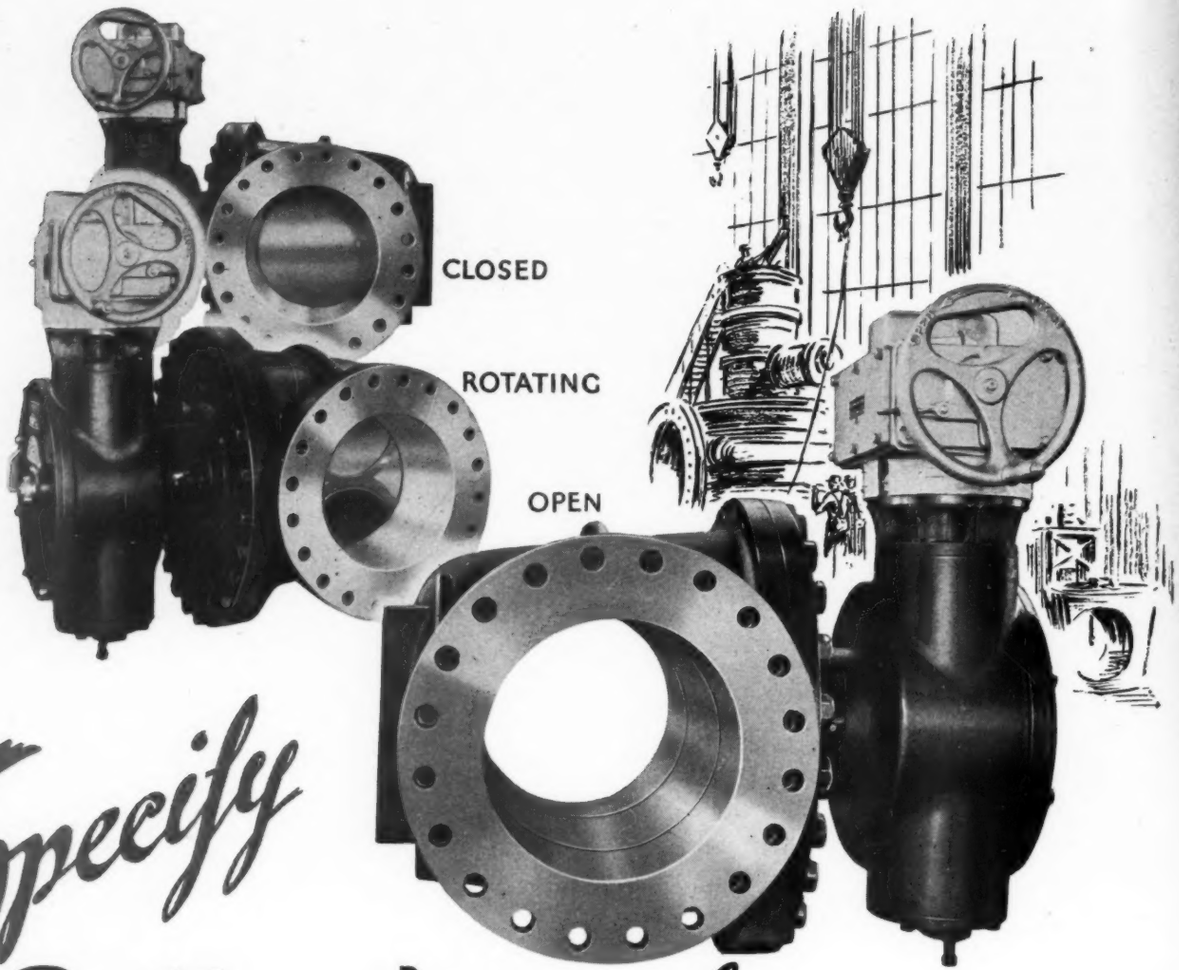
In Saint Clement's epistle to the Corinthians, the Phoenix was used as an illustration of the doctrine of the resurrection. It had been recorded by the Egyptians as a symbol of immortality thousands of years previously, and it also appears on the coins of several Roman Emperors as a symbol of their own apotheosis or of the dawn of a more glorious era under their reign.

Hence—a person or thing of unique excellence; one of singular distinction or peerless beauty; a paragon.

Phoenix Meter Corporation

Water Meters & Meter Parts

PRINCE BAY, S. I. ◆ NEW YORK, N. Y.



Specify Rotovalves *for Maximum Operating Advantages*

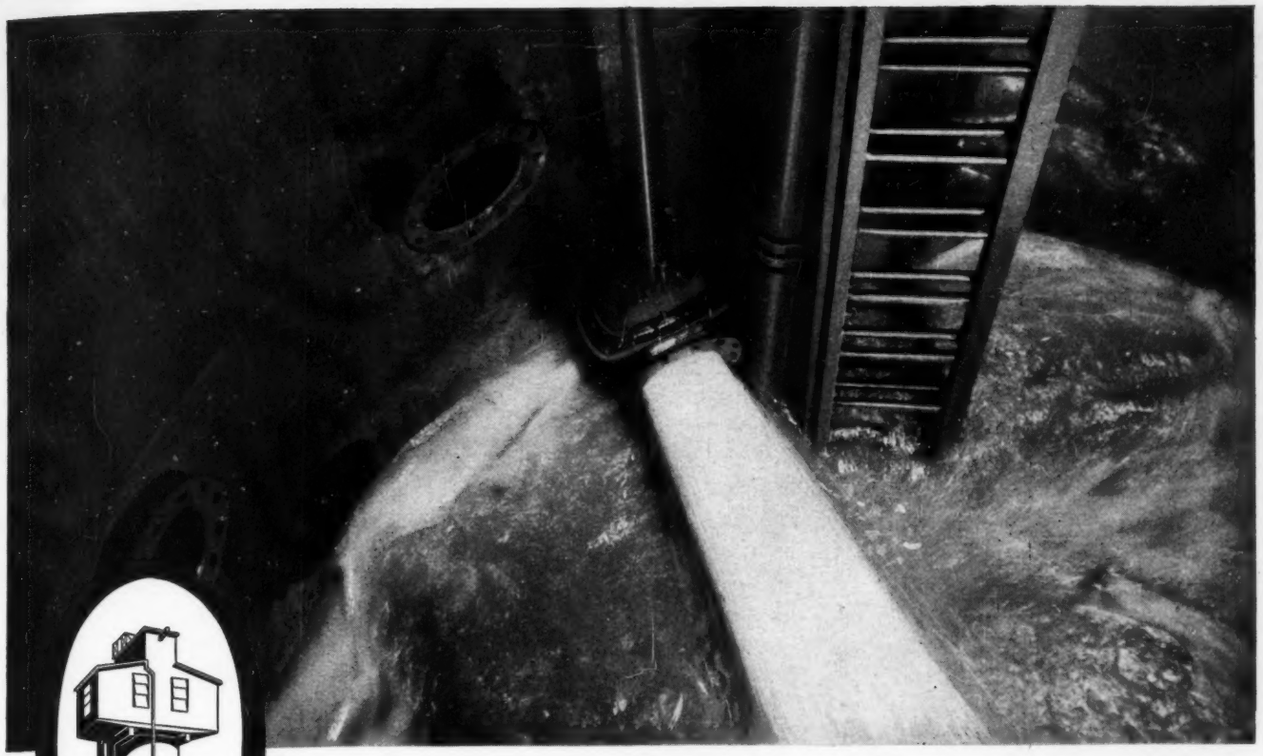
CONSULTING ENGINEERS, Officials and all other Waterworks men, regardless of how simple or complicated your problem is, you'll find your solution in SMITH ROTOVALVES!

For here is a cone valve design in which the plug:

lifts, rotates and seats . . . assures through, unobstructed flow . . . provides minimum loss, as the loss through a Rotovalve, when open, is no greater than it is through a pipe of equal diameter and length . . . is obtainable in sizes and with control mechanisms meeting a wide range of services . . . may be operated by either manual or hydraulic means, or combined motor and manual mechanism as shown . . . supplies quick, positive operation!

The swing to Smith Rotovalves is unmistakable, as proven by installations in modern water works and new systems for Plants producing war materials. Specify SMITH ROTOVALVES in your next job!

S. MORGAN SMITH COMPANY YORK, PA.

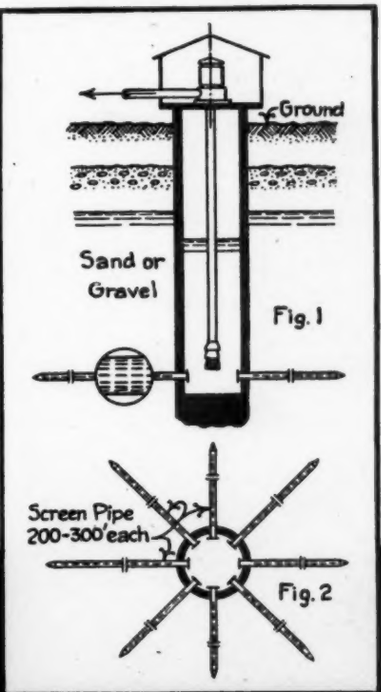


Quenching a Powder Plant's Thirst!

Industrial production for War requires fantastic quantities of water. Take the manufacture of gun powder. One of the world's largest smokeless powder plants uses over 65 million gallons of water daily—more than the consumption of a city of a half-million population. Other large ordnance works consume water in gallonage running into multiple millions.

These unprecedented demands are being met by the Ranney Method of Water Collection, a low-cost, self-contained and centralized water-producing unit. In this process a concrete caisson is sunk into the ground and then sealed at the bottom (see Fig. 1, right). Horizontal screen pipes, running in length to 300 feet, are pushed radially into the water-bearing formations at selected levels (Fig. 2). The above photograph shows water gushing into a Ranney Collector through one of the pipe-portholes, the number of which is determined by the quantity of water required. The capacity of any collector can be increased by driving screen pipes through the additional portholes.

The Ranney Method of Water Collection ranks among the War's great and lasting industrial developments. Because it must be a factor in the post-war planning, it is wise for those interested in water for industrial and municipal purposes to investigate its potentialities now.



Ranney WATER COLLECTOR CORPORATION OF NEW YORK

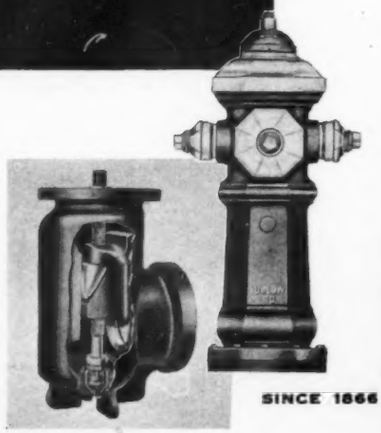
HEYBURN BUILDING • LOUISVILLE, KY.

Except "every man in service"

When and if such announcements are made over our radios, "every man in service" will have very special significance. Then, the hours of extra effort and weeks of special training by city fire departments will prove their worth.

Also proving their worth will be the army of Ludlow Hydrants — then "in service" as never before. Ludlow Hydrants are always ready for action, prepared to deliver a steady flow of water, instantly and with minimum shock. They operate on the famous slide gate principle, which provides smooth action of free moving parts and assures long, trouble-free service. If damaged in a blackout collision or otherwise, the Ludlow Hydrant will not flood, because it is wedge-locked when closed. These, and other superior construction features, make them ideal for that new defense area in your city! Send for Catalog.

THE LUDLOW VALVE MFG. CO., INC.
TROY, NEW YORK



SINCE 1866

LUDLOW HYDRANTS

Ludlow Construction. Self-releasing 30° angle wedges and free-floating gates, self-adjusting to seats, afford smooth, trouble-free performance, long service. Opening and closing of hydrant automatically opens and closes drain, located at lowest point. Clogging is prevented. Gate is wedge-locked, when closed, to prevent flooding. All working parts may be lifted through top of hydrant for easy inspection. Top and bottom bodies bolted together at ground line.

REPORTED FOR ACTIVE DUTY
WITH ARMY, NAVY AND MARINE WATER AND SEWERAGE SYSTEMS EVERYWHERE!

NEW RIVER MARINE BARRACKS · NEWFOUNDLAND NAVY · CAMP CROWDER · FORT READ · CAMP · A CANAL · SAN · NEW · RIVER · MOUTH · FORT · R ORD- · NANCE · ROADS · HU · DNANCE · WORKS · IELD · ELLIS · Y FIELD · · CAMP · SLE · FOR · IVER ORD- · NANCE PI · RAD- FO · ORT JACK- · SON · FOR · ING · FUNSTON · · CAMP BOW · OD · WHEELER · FIELD · FOR · NANCE PLANT · PEARL HARBOR · AIR FIELD · LANGLEY FIELD · KANKAKEE · WORKS · FORT LE · DES MOINES ORDNANCE · PLANT · PRESQUE ISLE · RT DIX · CAMP · CANAL · SAN · NEW · RIVER · OUTH · FORT · AR ORD- · NANCE · ROADS · HU · RDNANCE · WORKS · ELD · ELLIS · EY FIELD · · CAMP · LE · FO · RIVER ORD- · NANCE PL · AD- FO · FORT JACK- · SON · FOR · NG · FUNSTON · · CAMP BOW · ELD · EDGEWOOD ARSENAL · DENVER · IT · WHEELER · FIELD · FORT KNOX · LAKE CITY ORDNANCE · HARBOR · WINDSOR LOCKS AIR FIELD · LANGLEY FIELD · KANKAKEE ORDNANCE · D WOOD · DES MOINES ORDNANCE · PLANT · VOLUNTEER ORDNANCE WORKS · NEWFOUNDLAND NAVY BASE · CAMP CROWDER ·

TYPE M REGISTER — INDICATOR — RECORDER

Used with Venturi Tube to measure flow through main water and sewage lines.

VENTURI TUBE

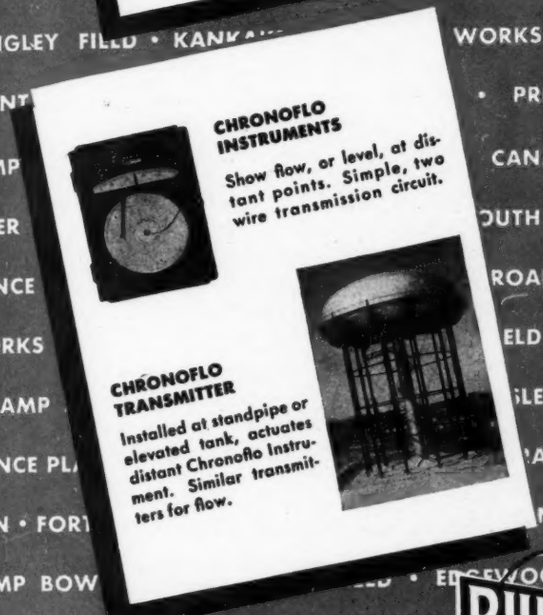
Has earned "50 year service stripe for meritorious service."

BUILDERS GAUGES

Are supplying filtration plants (military and municipal) with accurate rate-of-flow, loss-of-head, and level statistics on which safety and efficiency depend.

TYPE E FLOW CONTROLLERS

Widely used with Builders Gauges, regulate rate of flow through filter beds.



CHRONOFLO INSTRUMENTS

Show flow, or level, at distant points. Simple, two wire transmission circuit.

CHRONOFLO TRANSMITTER

Installed at standpipe or elevated tank, actuates distant Chronoflo Instrument. Similar transmitters for flow.

FLO-WATCH

Used with Venturi Tube or Nozzle, orifice, or Kennison Nozzle. Inexpensive, accurate mechanical meter.

KENNISON NOZZLE

For open flow, measures raw sewage, sludge, or effluent; trouble-free, accurate, simple, and easily installed.

BUILDERS
WATER AND SEWAGE PLANT *Instruments*

BUILDERS - PROVIDENCE, INC.
(DIVISION OF BUILDERS IRON FOUNDRY)
PROVIDENCE . . . RHODE ISLAND

Copper :- TOPS FOR PLUMBING PIPING ...YET MORE VITAL STILL TO "Keep 'Em Flying!"

WINNERS OF NAVY "E" AWARD

● Up until a few short months ago STREAMLINE copper pipe and bronze solder type fittings were installed in thousands of buildings where a permanently reliable plumbing or heating system was essential. They were used for air conditioning, for water service piping from main to building—for sewage disposal systems and a thousand other uses where dependability and long service life were of prime importance. They were, and still are, universally considered the finest materials that money can buy.

But today copper, bronze and brass have more vitally essential uses in the manufacture of munitions for our Army, Navy and Air Force—and today, too, the skill of the men and women of the Mueller Brass Co. plant and the full capacity of its productive machinery are now engaged 100% in doing their full share on this most important and gigantic task of our nation's history.

Today copper, brass and bronze are safeguarding the very life of the nation, but in happier days to come, they will again protect the health and promote the comfort and prosperity of its people in the form of STREAMLINE copper pipe and fittings. Our jobbers will stock them; our salesmen will sell them and our master plumbers will again install them.

STREAMLINE
PIPE AND FITTINGS DIVISION
MUELLER BRASS CO.
PORT HURON, MICHIGAN

● "Deferments" for chlorine cylinders are out for the duration. To conserve steel for Uncle Sam's tanks and battlewagons, the existing supply of cylinders has got to do full-time duty. Mathieson and the chlorine industry can't count on new cylinders "as usual."

Do your part by returning your "empties" quickly . . . regularly. You'll be helping Mathieson to maintain a dependable supply of chlorine for your plant. Don't let idle cylinders "dodge the draft" . . . "Keep 'em rolling!"

Plan now to attend the Wartime Conference of the American Water Works Association, Chicago, Ill., June 21-25, 1942.

THE **Mathieson Alkali Works** (INC)
60 E. 42ND ST., NEW YORK, N. Y.

LIQUID CHLORINE . . . HTH . . . SODA ASH . . . CAUSTIC SODA . . . BLEACHING POWDER . . . AMMONIA, ANHYDROUS and AQUA . . . BICARBONATE OF SODA . . . PH-PLUS (FUSED ALKALI) . . . DRY ICE . . . CARBONIC GAS . . . SYNTHETIC SALT CAKE . . . SODIUM CHLORITE PRODUCTS

WE'VE *Streamlined* OUR NAME FOR YOUR CONVENIENCE

INTERNATIONAL FILTER CO.

INFILCO

INCORPORATED

The decision to streamline our 48-year old name will not surprise our many friends in the Water Works field. They know we've outgrown it. In fact, the word "filter" is no longer even remotely descriptive of 70 per cent of the equipment we manufacture.

For many years the trademark INFILCO has identified rate of flow controllers, chemical feeders, hydraulic controls, mixing equipment, clarifiers, water softeners and zeolites, as well as filter equipment, engineered and manufactured by this organization for the Water Works field.

INFILCO

PRODUCTS

For Water Works

Aerators
Accelator Softeners and Clarifiers
Chemical Feeders and Proportioners
Clarifiers and Settlers
Coagulators
Filter Gauges
Flow Controllers and Gauges
Hydraulic Controls and Switches
Hydrodarco Purifiers
Lime Slakers
Mixing Basin Equipment
Operating Tables
Recarbonators
Sampling Devices
Sewage Treatment Equipment
Underdrains
Venturi Tubes
Water Filters and Softeners
Zeolites

INFILCO
INCORPORATED
325 W. 25TH PLACE, CHICAGO, ILL.
Formerly INTERNATIONAL FILTER CO.

IN hundreds of communities where Mathews Hydrants are standard, a couple of extra Mathews Barrels take care of every emergency and all routine service. These barrels, or standpipes, contain all working parts including main-valve and drain-valve seats. They are inserted through an outer protection and screwed up tight. Why not repair *your* accidents this easy way? Why not do *your* overhauling in indoor comfort? This is a reminder to Mathews owners to make a war-time check of their spare barrels. To everybody else it's a big reason for specifying Mathews.

Made by R.D. WOOD Company

ZECO and HI-ZECO Greensand Zeolite for water softening, filtration and iron removal. ZECO Manganese Zeolite for iron and manganese removal. COREXITE mineral for corrosion control and water stabilization.

★

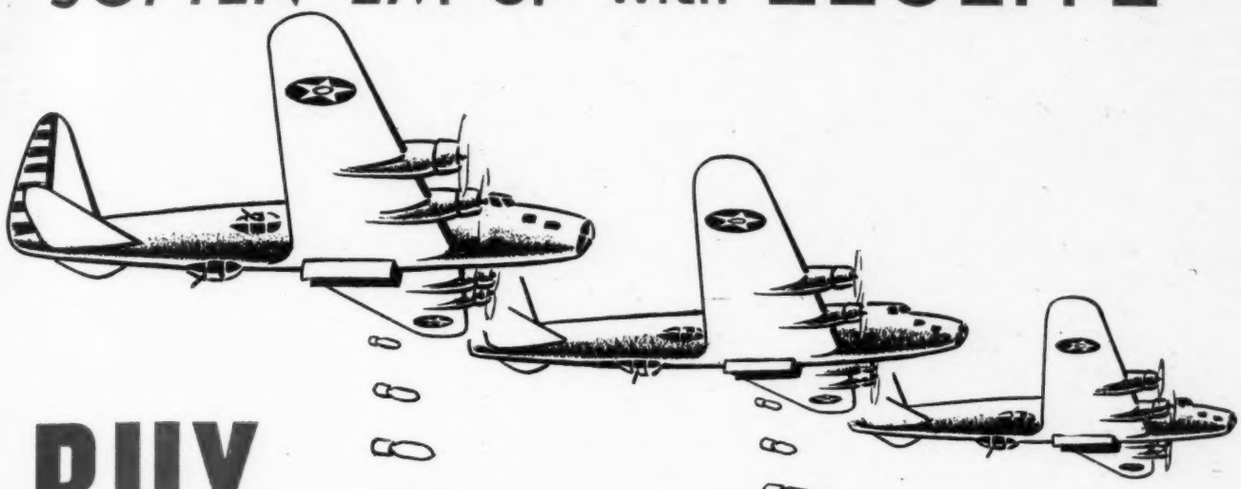
ZEOLITE CHEMICAL CO.

Sales Office
140 Cedar St., New York, N. Y.

Factory
Medford, N. J.

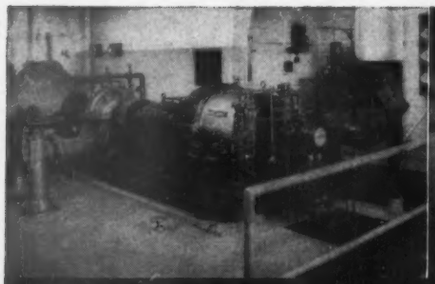
Pioneer Producer of GREENSAND ZEOLITE MINERAL

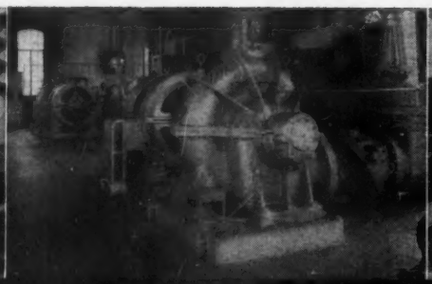
SOFTEN 'EM UP with ZEOLITE

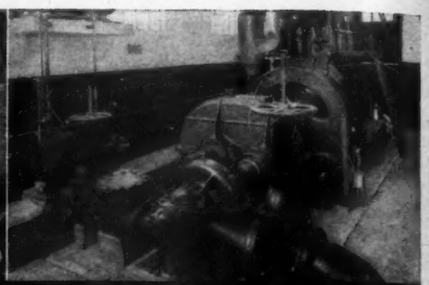


BUY WAR BONDS

ZEOLITE CHEMICAL COMPANY


STEAM TURBINE DRIVEN UNITS


MOTOR DRIVEN UNITS


DIESEL OR GAS ENGINE DRIVEN UNITS

WORTHINGTON EQUIPMENT
for
WATER SUPPLY

CENTRIFUGAL PUMPS

DIESEL ENGINES **GAS ENGINES**

MOORE STEAM TURBINES

Steam Condensers	Steam and Power Pumps
Feedwater Heaters	Steam-Jet Ejectors
Turbine Well Pumps	Sump and Drainage Pumps
Stationary Compressors	Portable Compressors
Rock Drilling Equipment	Construction Air Tools
Multi-V-Belt Drives	Water Meters
Speed Change Gears	Air Lifts

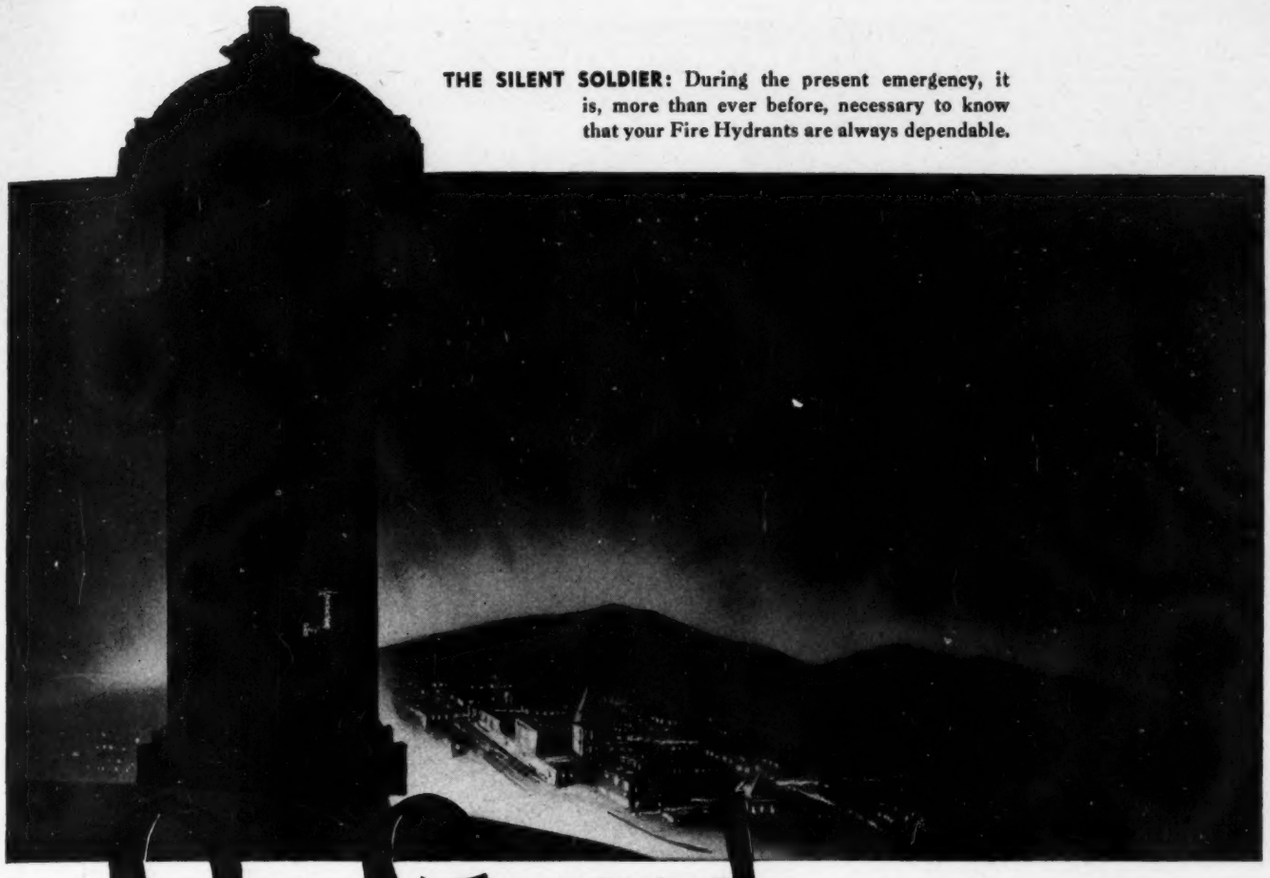
WATER PURIFICATION EQUIPMENT

Water Softeners	Pressure Filters

IC2-25

WORTHINGTON PUMP AND MACHINERY CORPORATION • HARRISON, NEW JERSEY

WORTHINGTON



THE SILENT SOLDIER: During the present emergency, it is, more than ever before, necessary to know that your Fire Hydrants are always dependable.

On Guard...

An Army and a Fire Hydrant must have one thing in common: DEPENDABILITY in an EMERGENCY. With the New Rensselaer "DEFENDER" this quality is triply★ assured.

★1. Easy to operate—Utilizes famous "Knuckle-joint" principle. Opens with water pressure.

2. Easy to service—All parts readily removed by one man. No special tools required.

3. Safe against Bombs—Can't leak due to stand-pipe breakage.

The name COREY has been discontinued in favor of the company name RENSSELAER

RENSSELAER
VALVE CO.
TROY, NEW YORK

Branch Offices:

Atlanta, Ga. — Los Angeles, Cal.
Chicago, Ill. — Pittsburgh, Pa.
Dallas, Tex. — San Francisco, Cal.
Kansas City, Mo. — Seattle, Wash.
Haverhill, Mass.

FOR POSITIVE RESULTS- -LOW COST OPERATION

Use... Investigate

LINK-BELT EQUIPMENT

STRAIGHTLINE COLLECTORS

CIRCULINE COLLECTORS

STRAIGHTLINE Sludge Collectors for the removal of sludge from rectangular settling tanks have proved their high efficiency, durability and economy through years of service. Book No. 1742.

CIRCULINE Collectors provide round tanks with the same important features which have made the STRAIGHTLINE Collector the acknowledged standard for rectangular tanks. Book No. 1642.

BIO-FILTRATION System For Treating Sewage

Much of the effectiveness of this system depends on the reaction between the filter effluent and the raw or partly treated sewage in the settling tank. STRAIGHTLINE and CIRCULINE Collectors have proved ideal for this process wherever used. Folder No. 1881.

BAR and TRITOR SCREENS

The STRAIGHTLINE Mechanically-Cleaned Bar Screen is the modern method of removing large suspended solids and debris from incoming sewage. Equally effective is the TRITOR Screen which is a combination of screen and grit chamber for medium and small size plants. Book No. 1587.

INDUSTRIAL WASTE SCREENS

Link-Belt Vibrating Screens are daily proving their efficiency and economy in the removal of objectionable suspended solids from industrial waste before the water is discharged into sewers or streams. Besides reducing stream pollution, the solids recovered, frequently are made into valuable by-product in some plants. Folder No. 1877.

STRAIGHTLINE Grit Collectors and Washers

effectively collect, wash and remove settled grit and separate it from putrescible organic matter. Consists of a scraper type collector which turns the material over and over and discharges it into a washing and dewatering screw which carries it up an incline to point of discharge. Folder No. 1942.

Other LINK-BELT WATER and SEWAGE TREATMENT PLANT EQUIPMENT INCLUDES: STRAIGHTLINE Mixers for Flocculation Tanks; STRAIGHTLINE Scum Breakers for Digestion Tanks; Elevated Diffusers; Traveling Water-Intake Screens; Roto-Louvre Dryers for sludge and other wet materials; P.I.V. Gear Variable Speed Drive for Pumps; Coal and Ashes Handling Machinery; Car Spotters and Haulage Systems; Shovels-Cranes-Draglines—Crawler, Tractor and Truck Mounted; and a complete line of elevating, conveying and power transmitting equipment. Catalogs sent on request.

LINK-BELT COMPANY

Specialists in the Manufacture of Equipment for Water and Sewage Treatment Plants

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Atlanta . . Baltimore . . Boston . . Buffalo . . Dallas . . Denver . . Detroit . . Grand Rapids . . Houston . . Huntington, W. Va. . . Indianapolis . . Louisville Kansas City, Mo. . . New Orleans . . New York . . Oakland, Calif. . . Pittsburgh . . Portland, Ore. . . Salt Lake City . . Seattle . . St. Louis . . St. Paul Wilkes-Barre. In Canada—Link-Belt Limited—Toronto Plant; Montreal; Vancouver; Swastika

Shovel-Crane-Dragline Division—Link-Belt Speeder Corp., Chicago and Cedar Rapids

8796-A

A Tap-full or a Torrent

PEERLESS PUMPS—PROVIDE WATER FOR MOST EVERY INDUSTRIAL, COMMERCIAL AND DOMESTIC USE

In size, type of drive, choice of lubrication, for any depth or any practicable head, with lasting quality and sustained performance, your safest and most economical investment for lifting water is a Peerless Pump. Peerless Pumps' wide range of capacities can provide from 10 to 100,000 gallons of water per minute,—a tap-full or a torrent.

PRE-ENGINEERING AND PRE-TESTING are the bases of customer preference. Peerless engineering and research are continual,—results are enduring. Many of the "firsts" in water lifting are Peerless innovations.

PEERLESS PUMPS

SERVICE AND INFORMATION are factors in customer preference. Peerless Distributors are located in every state in the Union and every Allied Nation. Consult your nearest one for pre-sale information, post-sale service.

CUSTOMER PREFERENCE. Evidence of Peerless leadership is the roster of Peerless owners which contains thousands of industrial and commercial concerns whose names and products are household words, the world over. The benefits of the judgment and experience of their engineers are yours when you buy a Peerless Pump.

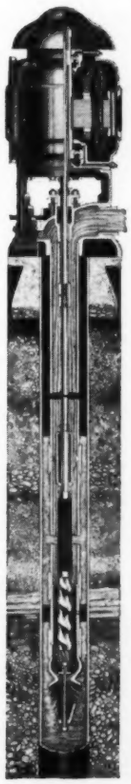
PEERLESS PUMPS' COMPLETE LINE INCLUDES

Deep Well Turbine Pumps
All forms of drive; electric direct-connected, right angle drive and belted heads.
Hydro-Foil (Propeller Type) Pumps
Hi-Lift Pumps
Other Peerless Types Centrifugal Pumps
Bilge Pumps
Sewage Pumps
Mine Sinker and Mine Dewatering Pumps
Gasoline and Fuel Oil Direct Refueling and Transfer Pumps
Domestic Water Systems and Jet Pumps

BULLETINS are available that illustrate and describe their application. Write for your copies.

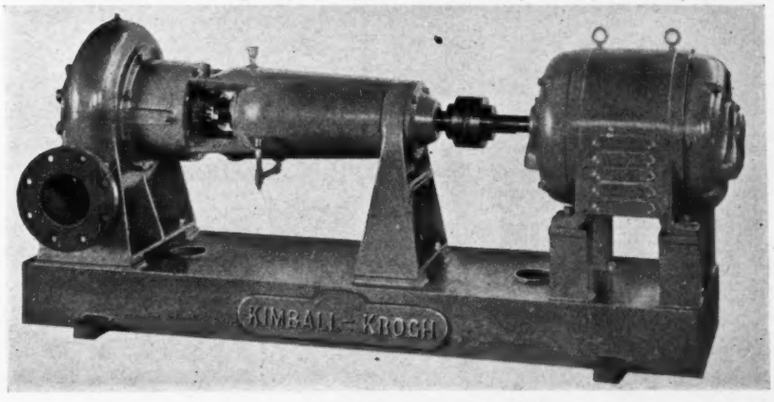
Kimball-Krogh Non-Clogging Type Horizontal Sewage Pump

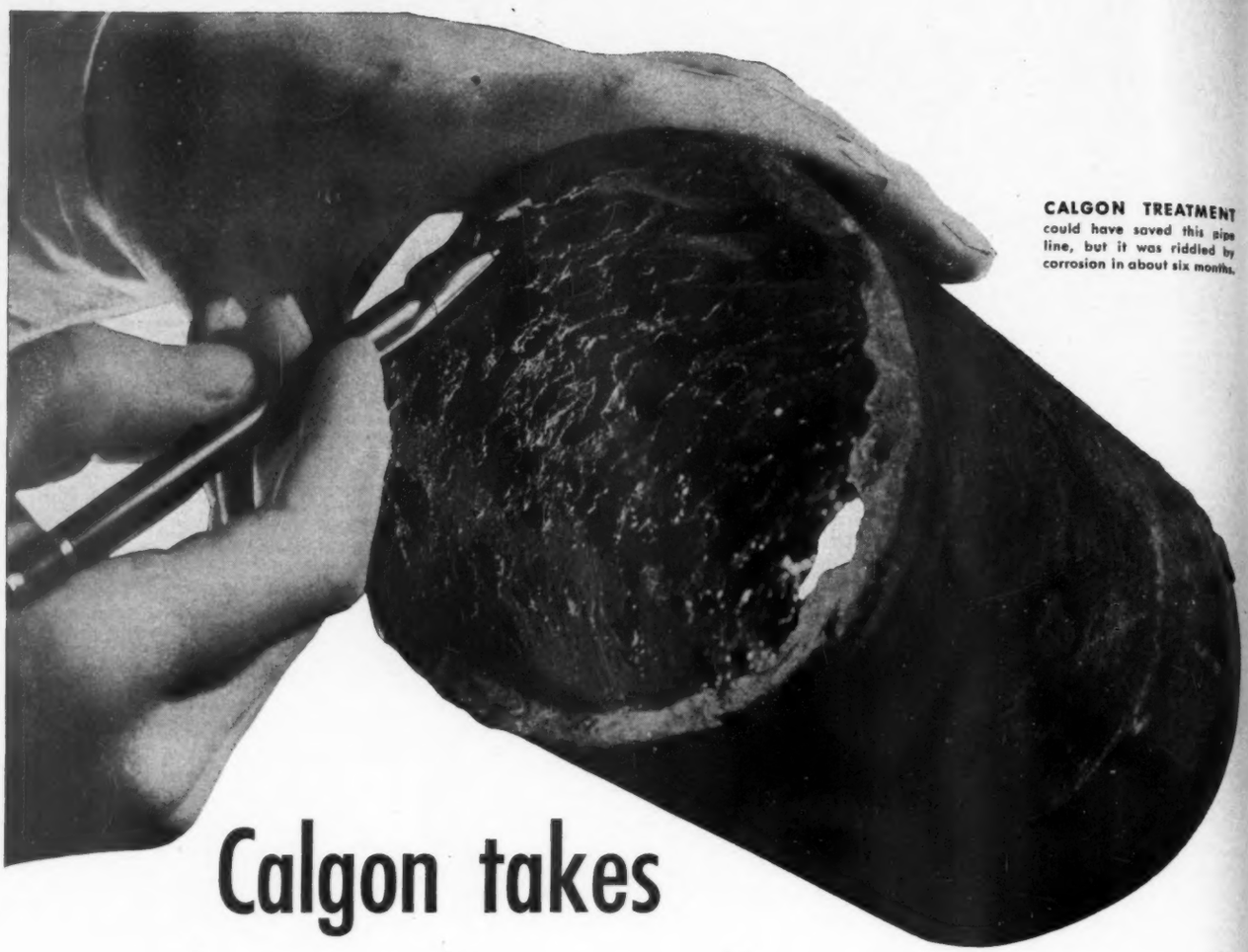
Peerless Deep Well Turbine Pump



Peerless Hi-Lift Pump

PEERLESS PUMP DIVISION — FOOD MACHINERY CORPORATION
1250 Camden Ave., S. W., Canton, O. 301 West Ave. 26, Los Angeles, Calif.
FACTORIES: Los Angeles, San Jose and Fresno, Calif.; Canton, Ohio





CALGON TREATMENT could have saved this pipe line, but it was riddled by corrosion in about six months.

Calgon takes the teeth out of corrosion

Calgon solves 4 water works problems

1. **Prevention of scale** from hard, high-bicarbonate waters. Calgon, added at the plant, prevents scale formation in mains, meters and hot-water heaters, throughout the system.
2. **Corrosion Control**—Calgon forms a thin protective film on metals and metal oxides at pH values of 5.0 and higher. This reduces the attack of oxygen to such an extent that corrosion ceases to be a problem.
3. **Prevention of "red water"**—Calgon prevents the precipitation of dissolved iron. Thus "red water," either from iron initially present in well water or from corrosion, can be eliminated.
4. **Stabilization of water** following lime or lime-soda softening. Calgon's ability to prevent precipitation of calcium carbonate stabilizes water to the ends of the system.

HOW to tame corrosion's bite and overcome "red water" have been stubborn problems for water works operators. Adding alkali to increase pH, for the purpose of laying down a protective scale coating, usually resulted in excess scale deposits near the plant and little, if any, protection at the ends of the lines. Operators were constantly striving for complete stability—freedom from corrosion on one hand and minimum scale on the other.

Calgon works a "pincers" attack on the problem. By laying a thin phosphate film over all metal surfaces, Calgon reduces oxidation to a minimum, at the same time preventing undesirable deposition of calcium carbonate. Thus Calgon works in lime-soda softened water as well as in naturally soft water. "Red water" quickly disappears even at the extremities of the line.

In solving the corrosion problem, Calgon gives you a bonus of longer pipe life. This is important today as pipe is becoming increasingly difficult to get. Only 1 to 5 ppm. of Calgon are needed for the most severe cases of corrosion. This brings the cost of the treatment well within the budgets of most water works departments.

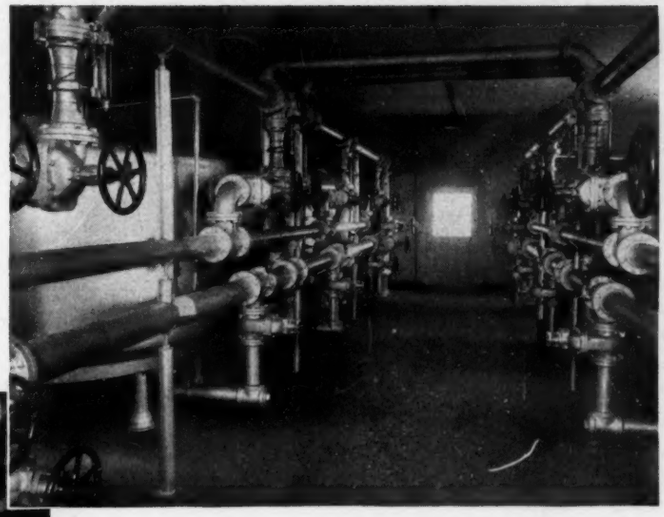
We'll gladly send you complete details with instructions and a sample of Calgon* to conduct your own tests. Just write.

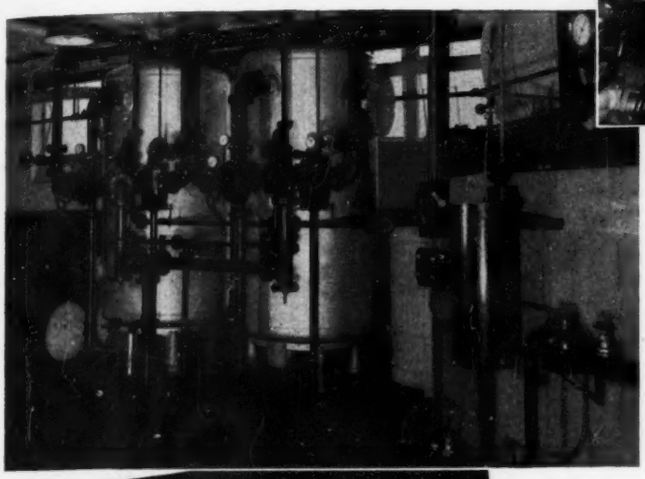
** Calgon is the registered trade-mark of Calgon, Inc. for its sodium phosphate glass products.*

calgon, inc.

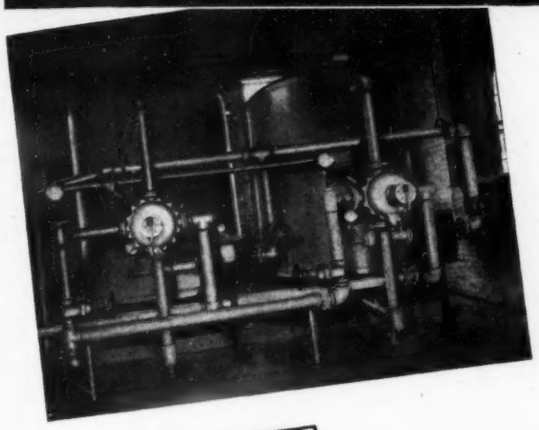
HAGAN BUILDING PITTSBURGH, PA.

A *Complete* Service . . .





an *Undivided* Responsibility



IN the production of equipment for the conditioning of water and the treatment of sewage, Graver offers a service broad in scope, yet unified under the control of men long experienced in this highly specialized work.

This service is *complete*, including designing, engineering, and fabrication of every unit, and provides the unique and highly important advantage of a single responsibility for the entire job.

Whenever you require equipment for the conditioning of water supplies, or for the treatment of sewage you will find it particularly advantageous to consult Graver. There is not the slightest obligation in doing so.

WATER SOFTENERS
FILTRATION SYSTEMS
CLARIFIERS
SEWAGE EQUIPMENT
STEEL STORAGE TANKS
VAPOR CONSERVATION SYSTEMS
WELDED CONSTRUCTION
STRESS RELIEVING
X-RAYING
FABRICATED STEEL AND NON-CORROSIVE PLATE

GRAVER

GRAVER TANK & MFG. CO., INC.

NEW YORK
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4809-14 TOD AVE.
EAST CHICAGO, IND.
CABLE ADDRESS — GRATANK

CHICAGO
TULSA

42-35-W

MANPOWER A PROBLEM?

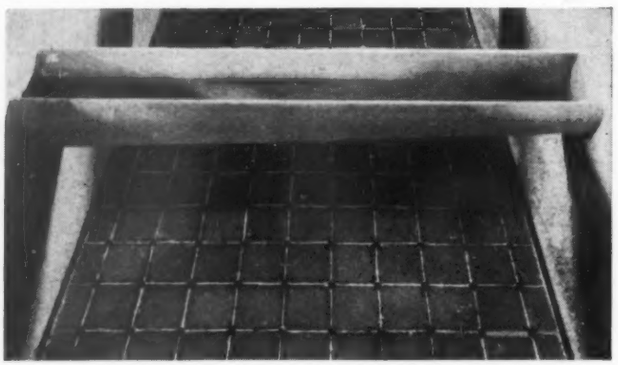
You can save time and trouble with the Aloxite Brand Porous Filter Underdrain System

IF selective service and war production has hit the manpower at your filter plant, here's a way to help solve the problem. You can save man hours and reduce filter bottom troubles by installing the simple Aloxite Brand Porous Plate Underdrain System which eliminates all gravel.

In addition to saving time and labor today when both are at a premium, this system offers other benefits that are valuable at *any* time:

- *Reduced operating heads*
- *Uniform back wash*
- *Resistance to corrosion*
- *No loss of filter media*

A few of the more than 70 installations now giving exceptional service are shown below. Write for detailed information, and submit your problem.



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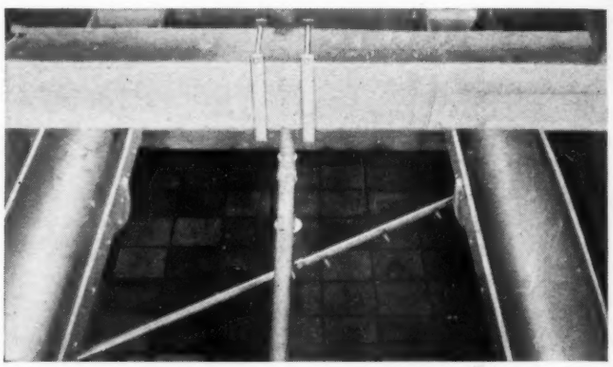

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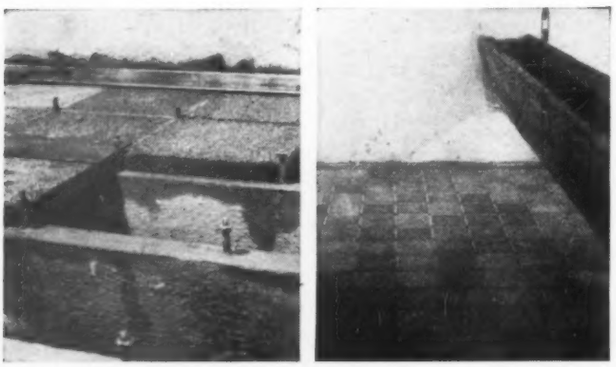

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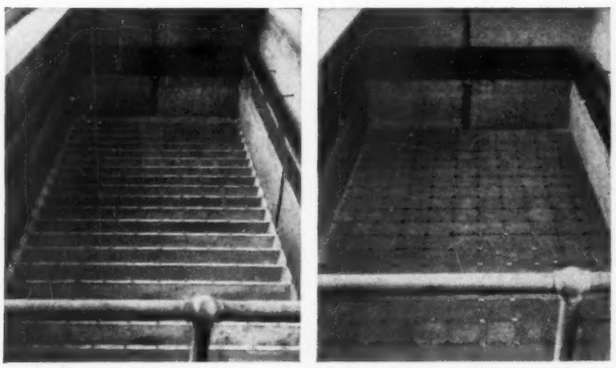

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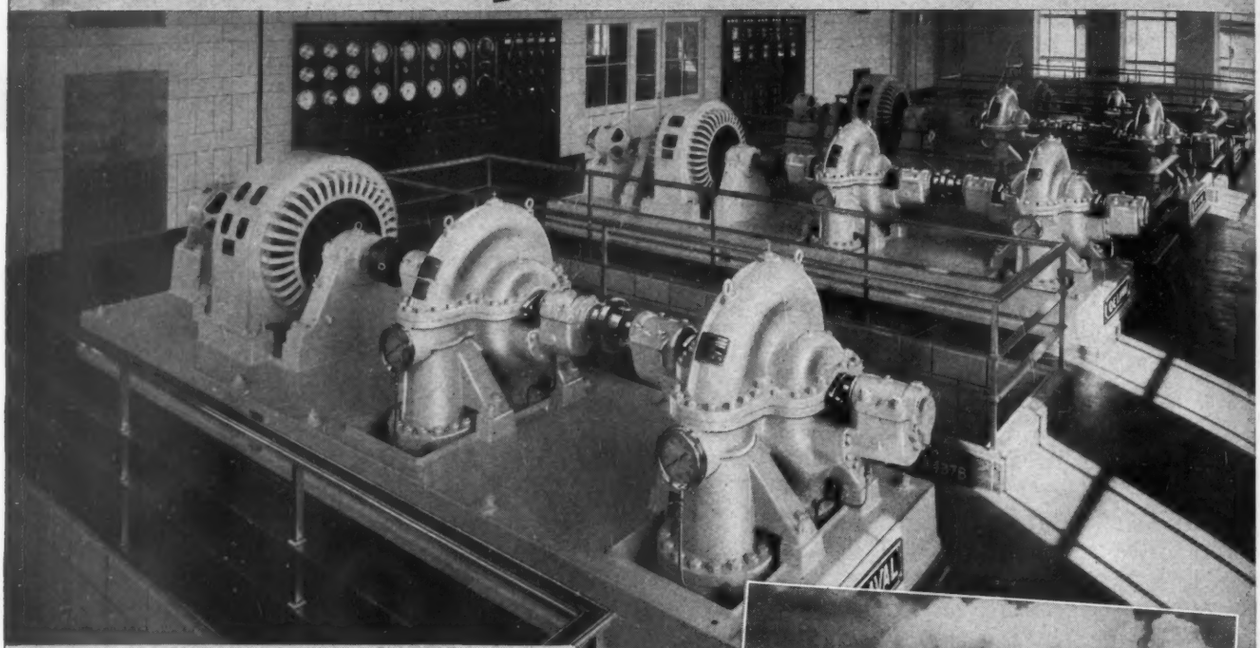

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CITY APPROVES FURTHER SURVEY OF WATER LEAKS

Large Central Area Will Be Checked Under New Contract

Gratified with results of a survey now being conducted, city council, at its weekly meeting this morning, authorized the Pitometer Co. of New York City, to make a further survey in an effort to find additional leaks in the city's water system.

Presently the company is completing a survey of the area bounded on the north by the city limits; east by the Lehigh river; south by the Little Lehigh, and west by 9th St. The new survey, which will require about three months, will be carried out in the area bounded on the north by the city limits; east by 9th, South 4th and South 5th Sts.; south, by the city limits, and west by the Little Lehigh and 17th St.

In a report submitted to Councilman Clarence R. Mensinger, director of the department of parks and water, the Pitometer Co. revealed that to date leaks discovered during the survey represented a wastage of 1,345,000 gallons of water daily. This included underground leaking of 974,000 gallons, and house waste located, under-registration of industrial meters, and unauthorized use for a fire line.

The unauthorized use of a fire line was located in a local industrial plant. A total of 290,000 gallons of water passed through this line daily. In addition, two meters at two other locations were found to be underregistering. Officials of the New York concern estimate that when the first survey is completed the total saving in the area will amount to about 1,750,000 gallons of water daily.

Included in the new area to be surveyed are a number of mains which are between 50 and 60 years old. It is believed by officials of the bureau of water that a number of leaks will be discovered in these mains and repairs will result in further great saving of water.

Leaks which are being discovered through the survey could not be detected from the surface. Both Councilman Mensinger and William R. Schnabel, engineer and superintendent of the bureau of water, felt that the daily average pumpage of 19,500,000 gallons was exceptionally high for a city the size of Allentown. Two years ago the daily average consumption was 17,000,000 gallons.

The surveys, city officials point out will pay dividends since the saving, on the basis of the leaks thus far detected, amount to about $17,000.

Largest leaks found thus far include: 7th, north of Union Sts., 160-

1,750,000 gallons SAVED DAILY

...gallons.

The surveys, city officials point out will pay dividends since the saving, on the basis of the leaks thus far detected, amount to about $17,000.

Largest leaks found thus far in...

...authorized use of a fire line...

The unauthorized use of a fire line was located in a local industrial plant. A total of 290,000 gallons of water passed through this line daily. In addition, two meters at two other loca...

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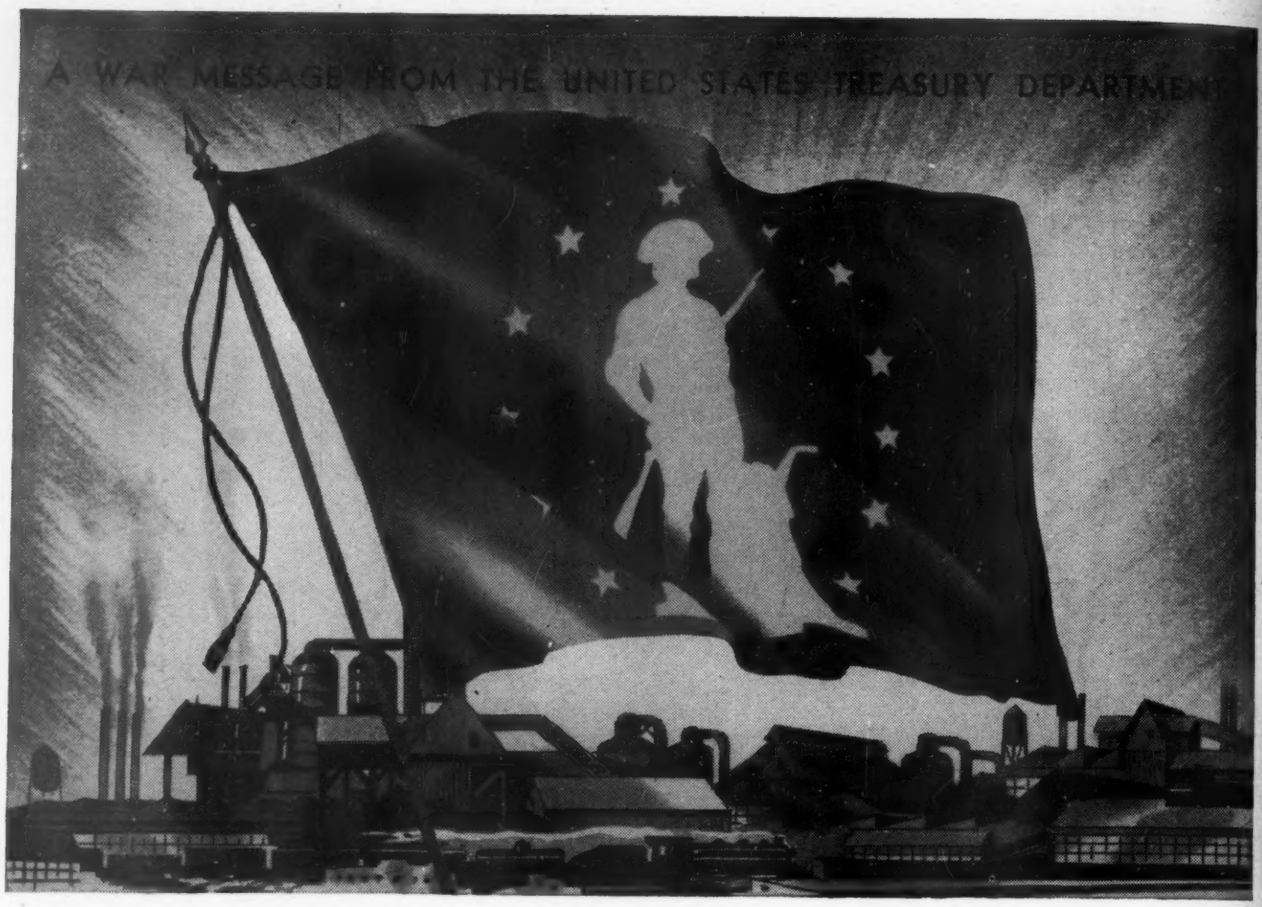

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Pipe size inches	Lb. per linear ft. Class 1	Class 2	Class 3	Class 4
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5	3350	....	....	....
6	2880	....	....	....
8	3100	....	....	....
10	2580	....	....	....
12	2370	3690	4920	....
14	2200	3850	5100	....
16	2120	3920	5150	....
18	2030	4050	5280	....
20	2290	4140	5360	....
24	2340	4280	5850	6340
30	2980	4550	7050	7100
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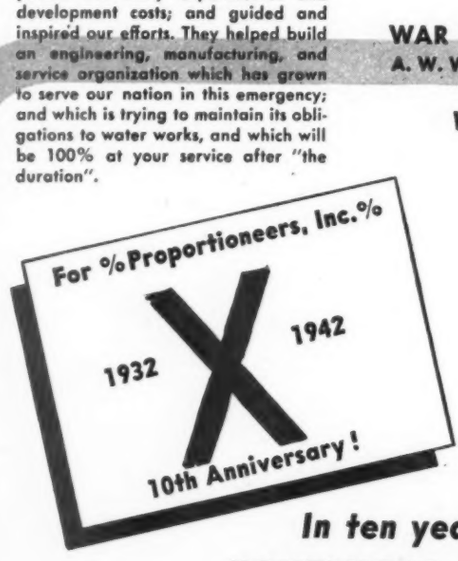

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COMING!

"The New Storeyard of Akron, Ohio"
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WENDELL R. LA DUE, Sup't & Eng'r, Dep't of Water and Sewage, Akron, Ohio.

"Gas Engine Operation and Performance"
Is the story of the performance record, dependability and economies of the gas engines of the medium sized sewage treatment works of Aurora, Ill. The first article to be published on the early Aurora installation of 1936 appeared in 1937 in this magazine. It is fitting that the story of the completed job and long-time performance records be told in the same publication in 1942, after a 15 month period of operation since past experience justified the complete severance of outside power and confident dependance on the by-product gas operated engine-generator sets of Aurora. This accomplishment represents another feather in the cap of the resourceful—
WALTER A. SPERRY, Sup't, The Sanitary District of Aurora, Ill.

"Sludge Heating with Live Steam"
Is a recital of experiences and practice followed at the main treatment works of the Los Angeles County Sanitation Districts which involves the economical practice of sludge, pre-heating with live steam enroute to the digestion tanks. The author is—
A. M. RAWN, Chief Engr. & Gen'l Mgr., Los Angeles County Sanitation Districts, Calif.

"Substitute and Alternate Materials for Service Pipe"
Is a timely and illuminating analysis of the advantages and shortcomings of service pipe materials now available to water works managers. The analysis covers lead of two weights; "Tube-loy" of two weights; wrought-iron; cast-iron and cement lined pipe. It presents a comparison of costs per foot for sizes ordinarily employed for water service lines, in addition the discussion of quality and service considerations. It serves as a splendid guide to those responsible for purchase of service line materials. The eminently practical and analytical author is—
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"Keeping Fresh Water Fresh"
Constitutes a problem on many systems where water storage is provided to serve outlying districts with fire protection, whereas domestic demand is relatively sparse. A scheme for securing positive displacement of water through elevated tanks for the purpose of preventing stagnation and water quality deterioration is described by—
D. R. TAYLOR, Plant Sup't, Roanoke, Va.

"Industrial Waste Treatment"
Amongst coming articles on treatment of industrial wastes the next will deal with "Chemicals and Their Application in Industrial Waste Treatment." This constitutes one of a series being contributed by the author of the recently published text, "Industrial Waste Treatment Practices"—
E. F. ELDRIDGE, Mich. Eng. Expt'l Sta., East Lansing, Mich.

"The Role of Bacteria in Corrosion"
Is revealed in a report of studies and experimentation which most definitely points to the fact that living organisms play an important part in corrosion of iron and steel. Evidence secured further conclusively reveals that corrosion and tuberculation of water mains, and red-water or black-water in dead ends and sluggish flow sections in particular, can be brought under control by checking bacterial growths in the film next to the walls of the pipes. The corrective tried successfully was that of maintaining residual chlorine in the water entering the corroding sections, this being more readily accomplished through ammonia-chlorine treatment. The work represents the most conclusive evidence yet produced that dead-end troubles are markedly intensified by, if not due almost in whole to, bacterial activity in the wall film on the pipe interiors and in bottom deposits. The author is—
A. H. THOMAS, Chief Chemist, Armco Research Laboratory, Middletown, Ohio.

VOL. 89, NO. 6 — JUNE, 1942

CONTENTS

Operation of the Gary Sewage Treatment Plant in 1941 229
By L. R. HOWSON, Designing Engineer, Alvord, Burdick & Howson, Chicago, Ill., and W. W. MATHEWS, Superintendent, Sanitary District, Gary, Ind.

Gate Valves 238
By ROGER W. ESTY, Superintendent, Water and Sewer Board, Danvers, Mass.

Hydrant Maintenance 241
By E. T. CRANCH, President and Manager, New Rochelle Water, Co., Rochelle, N. Y.

Water and Sewage Patents 243
By JULIAN F. SMITH, Associate Editor, Hooker Scientific Library, Central College, Fayette, Mo.

Arkansas Water and Sewage Conference Well Attended 244

A New "Philadelphia Story" 245
By MARTIN J. McLAUGHLIN, Chief, Bureau of Water, Philadelphia, Pa.

Fume Trap for Diesels 247
By DON CALDERWOOD, Engineer, Pennichuck Water Works Company, Nashua, N. H.

Service Shooting 248
By LaVERNE TRENTLAGE, Ass't Sup't, Water Department, Elgin, Ill.

Drilling and Developing Deep Wells 251
By J. ARTHUR CARR, Superintendent, Water Department, Ridgewood, N. J.

Canadian Section Turns Out Strong 253

Invisible Light Used to Fight Sabotage 260
By R. E. APPEL, Worner Products Corp., Chicago, Ill.

Operation of Distribution Systems Under Bombing Conditions 261
By RICHARD BENNETT, Hydraulic Engineer, Phoenix, Ariz.

Ohio Section's Fourth Conference on W. W. Management 266
By JOHN S. GETTRUST, Sup't of Filtration, Akron, Ohio

Experiences With Calgon Treatment at Bristol, Conn. 269
By I. LAIRD NEWELL, Chemist, The Henry Souther Engineering Co., Hartford, Conn.

Installation of Palmer Filter Bed Agitators 271
By SAMUEL H. MITCHELL, Chief Operator, Filtration Plant, Allentown, Pa.

Sewage Treatment at Appleton 273
By C. O. BAETZ, Superintendent, Sewage Treatment Works, Appleton, Wis.

Wisconsin Sewage Works Operators Meet at Wausau 275
By R. W. FRAZIER, Superintendent, Sewerage Commission, Oshkosh, Wis.

Control of Odorous and Destructive Gases in Sewers and Treatment Plants 277
By CHAS. C. HOMMON, Supervisor of Sewage Treatment, Canton, Ohio

Contents of Horizontal Cylinders 282
By J. TARRANT, Assoc. M.Inst.C.E., A.M.I. Mech. E., Ruislip (Middlesex), England

Editorial 284

Meetings Scheduled ..... Ad. Page 116

H. P. GILLETTE, President; E. S. GILLETTE, Vice Pres. and Publisher; L. H. ENSLOW, Vice Pres. and Editor; JOHN C. BLACK, Managing Editor; Associate Editors — J. R. BAYLIS, A. M. RAWN, H. A. FABER; H. J. CONWAY, Make-Up Editor; D. G. LEDGERWOOD, Advertising Editor.

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2. Test them when brought into the shop for repairs, keeping a record of these tests. Test at rate of flow in gallons per minute.

3. Repair them carefully, especially the chambers and gear trains, keeping a record of repair costs, both parts and labor.

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PROPER meter conservation, instead of *increasing* the cost of water to the consumer, has proved a means of *minimizing* such costs by reducing water works operating expenses . . . to the extent that in some instances water rates in the community have been substantially lowered, yet the water company has had funds to set aside for improvements and extensions of the system.

Water companies, when starting a regular meter conservation program of testing and repairing, will find that they have been losing much revenue due to under-registration of meters. Customers will no doubt complain of high water bills when meters have been restored to accuracy, but bills will decrease when formerly unsuspected leaks have been stopped and carelessness in the use of water has been eliminated. Records kept will allow a much closer control over leakage losses which may occur from time to time.

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Your experienced Trident representative will be glad to cooperate with you in your meter conservation program . . . and, in addition, you are invited to write us for our new Booklet #597. It is a thorough and informative study of this important subject, based on actual practice.

TRIDENT METERS
LET'S MAKE THE MOST OF WHAT WE'VE GOT
INTERCHANGEABILITY

WATER WORKS & SEWERAGE

VOL. 89, No. 6 *A Gillette Publication* JUNE, 1942

OPERATION OF THE GARY SEWAGE TREATMENT PLANT IN 1941

By L. R. HOWSON*
Designing Engineer
ALVORD, BURDICK & HOWSON
CHICAGO, ILL.

and

W. W. MATHEWS
Superintendent
SANITARY DISTRICT OF
GARY, IND.

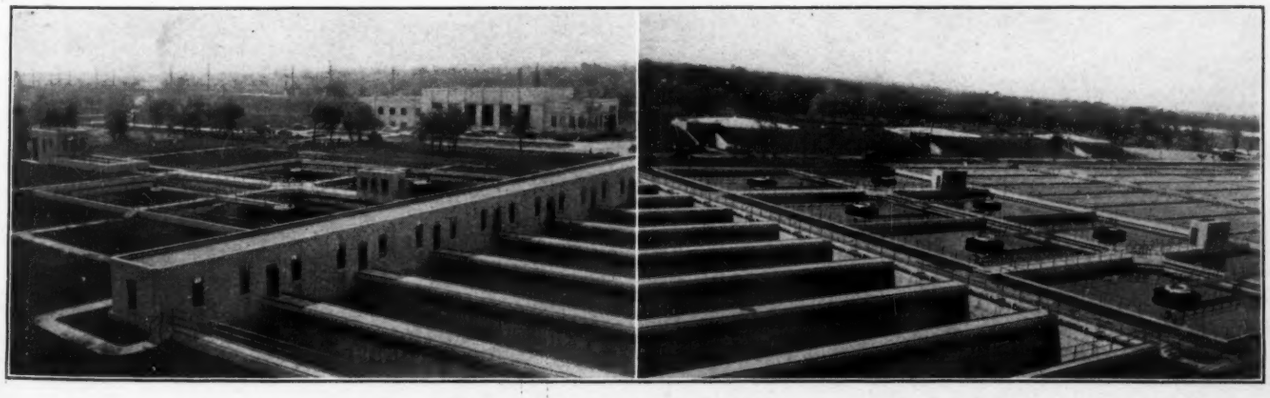
THE sewage treatment plant of the Sanitary District of Gary, Indiana, has now completed its first full calendar year of operation. This followed a preliminary tune-up period of about three months in the latter part of 1940.

The plant went into operation on August 23, 1940, and complete treatment was started on September 17, 1940. From two to three weeks additional were required to build up an activated sludge, so that normal operations really began early in October, 1940. The Gary activated sludge plant is designed and equipped to dispose of garbage along with the sewage. However, in the first year of operation no garbage solids were handled so that the operating results herein discussed are those experienced in the treatment of a domestic sewage of about average strength.

No industrial wastes that materially affect its operations are received at the plant, although one industry dumps ferrous sulphate from steel pickling at two or three day intervals. That there is, however, considerable industrial load is evidenced by the 5 day B.O.D. averaging .244 lb. per capita per day, approximately 50 per cent more than the normal purely domestic sewage.

In general, this article will be restricted to discussion of operating results. However, there are certain features of design and construction which are unique or believed to be sufficiently important in accounting for the excellent operating results to warrant special mention.

*The senior author has the distinction of being President of the American Water Works Association.—Ed.



Two Views of the Gary Plant

Left: Power House and Pumping Station beyond the Primary Clarifiers; on left the Screenings House and Grit Chambers; in foreground the Aeration Control Gallery and Aeration Tanks. Right: Battery of 4 Primary and 4 Secondary Digestion Tanks in background; Aeration Tanks and 8 Secondary Settling Tanks with Sludge Beds beyond.

The Plant in General

The treatment plant at Gary is designed to treat 40 MGD from a tributary population of 170,000. The sewage in 1941 had an average 5 day B.O.D. of 152 p.p.m. and suspended solids of 207 p.p.m. Plant facilities include the following:

Screening—5 25-in. comminutors.

Pumps—3 gas engine, 2 electric, total 90 MGD.

Grit Removal—2 basins, equipped with screw type conveyor, 1½ minute detention.

Primary Settling—4 radial flow tanks, 1 hour detention.

Aeration—10 straight through spiral flow type tanks, fixed tube diffusers, 5 hour detention.

Final Settling—8 radial flow tanks, 890 G.P.D./sq. ft.

Sludge Return—3 centrifugal units, 15 MGD.

Sludge Digestion—8 tanks, 6 cu. ft./cap. (incl. garbage), 180,000 cu. ft. gas storage.

Sludge Drying on Beds—2 sq. ft./cap.

Power Plant—2 gas engine rotary, 3 electric centrifugal blowers, total 35,000 c.f.a.

Garbage Grinding—2 units, 20 T./hr.

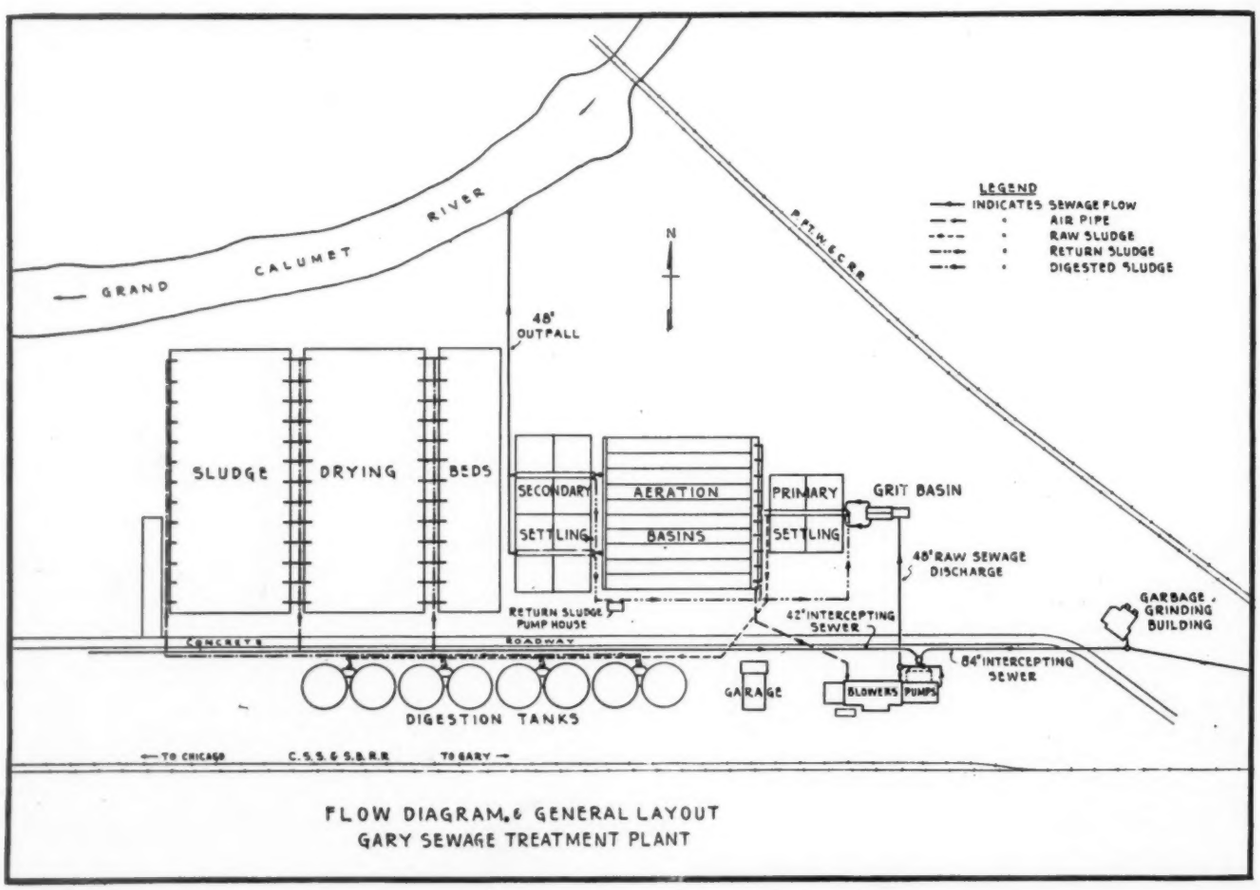
From the flow sheet through the plant it will be noted that the plant layout is unusually compact and the direction of flow maintained from the point where the sewage first enters the plant to its final discharge into the Grand Calumet River. This compactness of layout and the directness of flow are in large part responsible for the low construction cost of approximately $43,000 per MGD capacity, a figure considered especially low in view of the liberal and special features of design which are discussed at a later point.

The present population of Gary is approximately 115,000 people. The plant is designed for 170,000 people with a sewage flow of 40 MGD. Prior to the depression, Gary's growth averaged 5,000 people per year. Within the past few months it has again taken a steep upturn due to the great activity in the steel mills and related industries. For a city which has grown from barren sand dunes to over 100,000 people in 25 years, liberal design bases were indicated. Further, industry attracts industry and the design and installation recognize the possibility of rapid expansion in industrial load at Gary.

The Power Plant

The power plant structure houses the comminutors, pumps and blowers. The sewage pumping equipment consists of two electric motor driven Worthington pumps rated at 15 MGD each and three gas engine driven units (Worthington pumps and engines) rated at 20 MGD each. Total pumping capacity is 90 MGD. The speed of the gas engine driven pumps is regulated by the elevation of the sewage in the suction channel through float connection to the throttle. The delivery varies from 15 to 25 MGD per unit in normal operation.

Five air blowers are provided with a total capacity of 35,000 cu. ft. per minute. Two of these are gas engine driven rotary, displacement type (Roots Connersville blowers, Cooper Bessemer engines), with a total capacity of 14,000 cu. ft. per minute (.5 c.f.a. per gallon at plant rating). The other three are of centrifugal type (Elliott Co.) of 5,000, 7,000 and 9,000 cu. ft. per minute, respectively. There is large reserve capac-



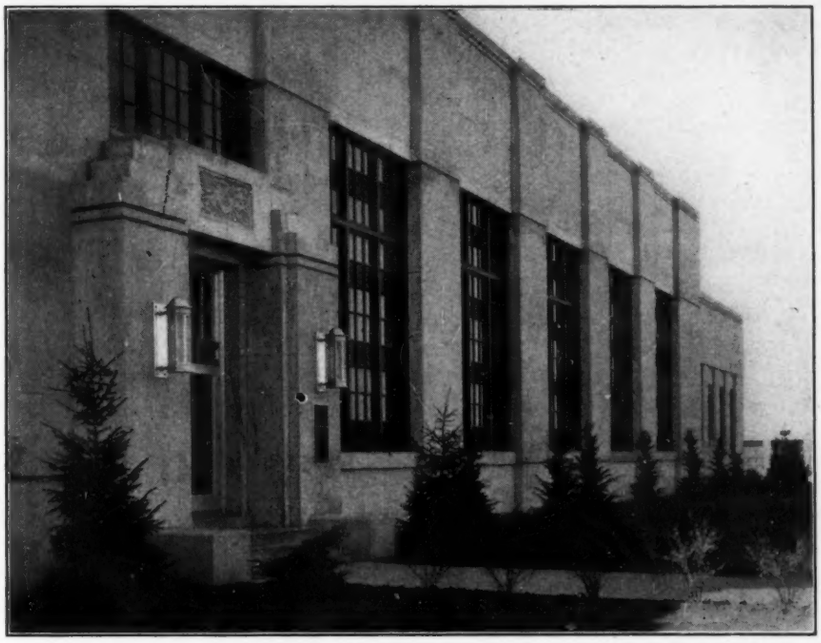
Flow Sheet of the Combination Sewage and Garbage Disposal Plant of Gary

ity in both pumping and compressor installations, a reserve believed especially desirable in a rapidly growing industrial area.

The offices and laboratory are located in the power plant building on the second floor directly above the pumping installation. On account of this utilization of a part of the power building for offices and laboratory, acoustical ceilings are provided in the compressor and pump rooms and all gas engine equipment and displacement type blowers are mounted on vibration dampers. As a result the offices and laboratory are quiet and well adapted for the use to which they are put. This occupancy would be impossible without the sound deadening and vibration dampening installations.

Gary being a steel and cement city, the architectural design was developed to utilize those materials to their fullest advantage. The building, which is 240 ft. in length, is entirely of monolithic concrete, heavily reinforced with no expansion joints. The main entrance doors are of stainless steel.

The aeration tank control house, 300 ft. in length, and the garage and heater buildings are also of monolithic concrete.



Front of the Main Building
Reveals Effective Use of Architectural Concrete.

Sludge Digestion Liberal

Eight sludge digestion tanks, each 90 ft. in diameter by 20 ft. sidewall depth, are provided. This capacity is equivalent to 6 cu. ft. per capita. Of this capacity, approximately two-thirds is provided for the digestion of sewage solids and the other third for garbage solids. Five of these tanks are operated as primary tanks. These have fixed covers, Dorrco stirring devices, and fixed heating coils. The remaining three tanks, operated as secondary tanks, have floating covers, each with gas storage of 60,000 cu. ft. A sludge control house is located between each pair of tanks. It houses measuring and sampling equipment and the piping essential to stage operation of digestion.

Aeration Tanks

The aeration tanks are ten in number of the straight flow through spiral flow type. Air is supplied through fixed tube diffusers. (Chicago Pump Co., Carborundum Co. "Aloxite" tubes.) Operating experience to date has been most satisfactory. On one occasion when finely pulverized mineral wool from a silencer on the blower got into the air piping system and into the tubes, the advantage of having tubes easy to remove and clean was quickly demonstrated. The distribution of air has been at all times excellent.

Garbage Grinding

The Sanitary District of Gary is obligated to dispose of the garbage as well as the sewage. However, to date, due to the fact that the City of Gary is already equipped for the collection of garbage, the transfer of the garbage collection and disposal to the Sanitary District has not yet been made. Two Jeffrey Mfg. Co. grinding units each of 10 tons per day are installed for mascerating garbage which is to enter the sewage flow just ahead of the treatment plant.

No Underdrainage For Sludge Beds

The sewage treatment plant site is entirely of fine lake sand, having an effective size of from .10 to .15 m.m. The surface of the sludge beds is located about 5 ft. above the ground water plane. No underdrainage is provided. The sludge drains readily with the water passing direct to the ground water in the sand. No evidence of any clogging is observable.

Buoyancy Relief for Tanks

The fine lake sand at the plant site has a depth of 50 ft. or more. The bottom floor slabs of most of the tanks are located about 10 ft. below the ground water level. To prevent flotation when empty, each tank so located is provided with upward pressure relief consisting of 2-in. well points, 36 in. long, with the screen in the sand below the floor, the connecting pipe imbedded in and extending through the floor and capped at the inside floor line with a check valve permitting inflow and preventing outflow. These have operated very successfully. They greatly reduced the concrete quantities otherwise necessary to prevent flotation and cracking of floors.

Piping of Steel

Practically all piping through the plant is of steel construction with a minimum thickness of shell on sizes 6 in. and larger of ½ in. All pipe was protected by a spun bituminous coating on the inside averaging 3/16 in. in thickness, and by bituminous coating and asbestos wrapping on the exterior.

Comprehensive articles describing the Gary plant in detail have appeared in various technical publications (1) (2) (3) (4).

In discussing the plant operations, the sequence follows the sewage flow through the plant.

Screenings

All sewage entering the plant passes through a bank of five Chicago Pump Co. comminutors, all in parallel and each in a separate channel provided with hydraulic operated sluice gates at each end. The number of comminutors in operation depends upon the rate of flow and varies from two to five. The comminutors mascerate the coarse solids, very little material being retained in

the pits upstream. During 1941 the screenings removed manually averaged just under 0.10 cu. ft. per million gallons. Most of the material so removed is grit which settles out in the pits with rags, rubber balls, golf balls, tree branches, etc. No attempt is made to classify and tabulate each material separately. Cleaning of the pits is done when inspection shows it is required and, depending upon runoff, may vary from a few days to as much as two weeks.

The comminutors have given trouble free operation. The solids which are cut into fine particles settle readily with the other sewage solids. No excess scum has been noticed on the settling tanks as a result of their operation. It is apparent, however, that the rotating elements must be kept sharp at all times for efficient operation.

Grit Removal

Grit is removed by two Link-Belt Co. Straight Line collectors equipped with screw conveyors. The amount removed is less than would be expected from a combined system of sewers in the sandy terrain prevailing around the southern end of Lake Michigan. Total grit removed per million gallons averaged 3.51 cu. ft. Undoubtedly some of the grit is carried into the sewer system through cracks in several of the old brick sewers. Records show that after sustained rainfall with a subsequent raising of the ground water table and increased infiltration, the grit continues to come to the plant at above the average rate for some time after surface runoff has ceased. This has continued for as much as a month after the last rain storm. The ground water table apparently stabilizes at a minimum elevation during a dry period, and when this condition obtains, the flow reaching the plant is approximately twice the water works pumpage.

Putrescible matter in the grit averages 4.3 per cent with maximum of 10.2 and minimum of 0.77 per cent, respectively. Grit analyses are run weekly. An industrial railroad is used to haul the washed grit to low ground, where it is used as fill. No nuisance results.

Primary Clarification

Due to ground water infiltration noted above, the sewage reaches the plant quite diluted. The average efficiency of suspended solids removal in the primary clarification tanks is 44 per cent. The average removal of 5 day B.O.D. is 37 per cent. These reductions are influenced by a degree of coagulation in the primary clarifiers due to the ferrous sulphate discharged at intervals into the sewer system. When iron is passing through the plant, suspended solids reductions have been as high as 95 per cent, while reductions of 80 per cent are common. Average per cent reductions in suspended solids for a typical month, considering those days only on which ferrous sulphate was

The Pump Room

In foreground—Two 15 M.G.D. Worthington Pumps driven by 125 h.p. motors. Beyond—Three 175 h.p. Worthington Gas Engines driving 20 M.G.D. Worthington Pumps.

not discharged, was 31 per cent. Four 75 ft. square Dorr clarifiers (Sifeed radial flow type) are used for primary clarification. The average retention period for 1941 was 2.06 hours. Apparently the variation in removals of suspended solids and B.O.D. by the primary tanks has little effect on the quality of the final effluent or the air required to secure a satisfactory effluent.

Aeration

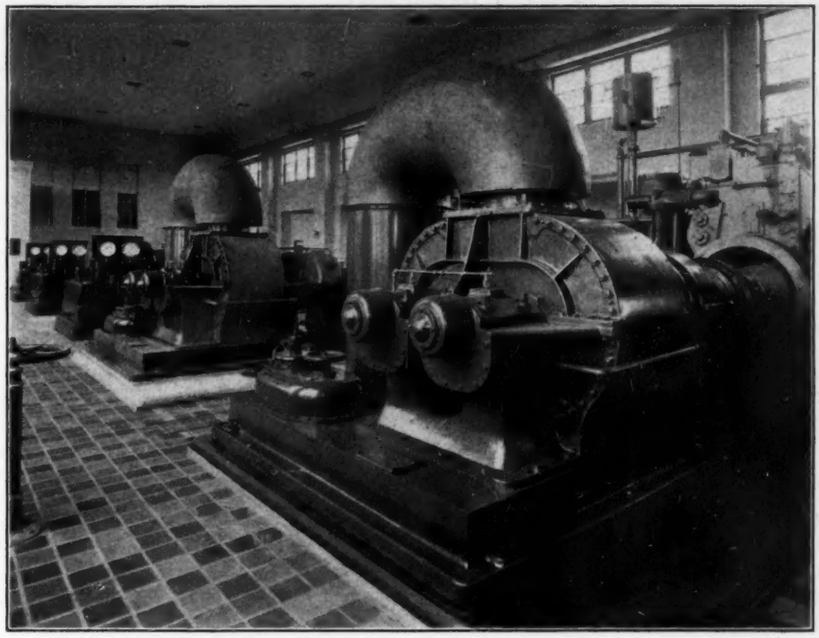
Aeration is in spiral straight through flow type aeration basins equipped with "Aloxite" diffuser tubes staggered on 16 in. centers on a fixed steel air header varying from 12 in. to 6 in. in diameter Basins are 300 ft. long, 30 ft. wide with 16 ft. water depth. Tubes are located 2 ft. above the basin floor. The tubes occupy a strip approximately 6 ft. wide along one side of each 30 ft. width basin. Tubes are 3x24 in. with permeability rating of 40. The spiral flow has kept the floor swept clean.

The number of aerators used has been either four or five, giving retention periods (monthly averages) of from a minimum of 3.56 hours to a maximum of 5.18 hours. Retention figure is computed, including return sludge. Air consumption has been from 0.44 cu. ft. per gallon to 0.61 cu. ft. per gallon of sewage. Each basin has individual air, return sludge and sewage meters. All piping, meters and recorders are located in a control house.

Mixed Liquor Solids and Return Sludge Rates

It was noted soon after starting operation that if the rate of return sludge was not held above 25 per cent of flow reaching the plant, septic conditions would develop because of sludge remaining too long in the secondary settling tanks, causing bulking. The practice now is to maintain the more rapid rate of return sludge, somewhat in excess of 30 per cent of flow. Average rate of return for 1941 was 29.7 per cent. Average rate of waste to primary clarifiers was 3.5 per cent of return sludge. Solids carried in the aeration tanks (monthly averages) have ranged from a low of 1,160 to a high of 1,855. Apparently by carrying 1,500 and 1,000 p.p.m. in the winter and summer, respectively, the best results ensue at Gary.

The following tabulation shows the principal operating data for the aeration tanks during each month of 1941.



Roots-Connersville Blowers and Cooper-Bessemer Engines at Closer Range

Month	Ave. B.O.D. p.p.m. Raw	Prim. Eff.	Ave. Air Input Cu. Ft./Gal.	Ave. Hrs. Retention	Ave. p.p.m. Solids in Aer. Tanks	Effluent p.p.m. Ave. B.O.D.	Ave. D.O.
Jan.	112	93	0.53	4.5	1303	15	6.0
Feb.	144	110	0.61	4.7	1710	8	6.0
Mar.	214	145	0.56	4.52	1855	9	5.8
April	181	121	0.51	4.13	1630	5	5.9
May	151	119	0.53	4.3	2019	9	5.1
June	124	80	0.51	4.18	1470	7	7.1
July	184	96	0.44	3.78	1460	12	3.5
August	170	121	0.55	4.73	1160	9	3.6
Sept.	194	92	0.70	5.18	1368	12	4.4
Oct.	115	53	0.44	3.69	1426	7	5.5
Nov.	124	49	0.36	3.56	1573	7	7.5
Dec.	114	74	0.44	4.26	1714	4	6.8
Ave.	152	96	0.52	4.29	1557	9	5.6

Limited Bulking Experience

Bulking has not occurred to date except during the first months of preliminary operation, and this was due to sludge remaining too long away from air in the secondary clarifiers. Periods of sustained drought have not affected the operation so that bulking occurs, as observed at some plants. While slightly more air may be used in the hot dry months, this was used to keep the dissolved oxygen up at the end of aeration. It has been determined that if dissolved oxygen in excess of 2 p.p.m. is maintained at the end of aeration, bulking will not occur at Gary. In passing over the weirs of the secondary clarifiers from 2 to 3 parts additional oxygen is absorbed from the air. Aeration, however, is not carried on with the idea of maintaining 2 p.p.m. minimum at the end of aeration, and except in the dry months it will average approximately twice this amount. At Gary one gas engine driven blower, operated at from 86 to 91 per cent of capacity, will on the average furnish from 0.4 to 0.5 cu. ft. of air per gallon of sewage. Rate of air supply is not changed during the day or week, although the blower has been slowed down to the lower rate at times of excessive runoff when tests show a surplus of oxygen at the end of aeration.

In March, 1941, a short experiment was conducted to induce bulking. For 12 days the solids were allowed to build up gradually to 2,800 p.p.m. with the air supply held to between 0.5 and 0.6 cu. ft. per gallon. The dissolved oxygen at end of aeration dropped from 4.0 to 0.4 p.p.m. and bulking appeared first in one of the eight secondary tanks. Rate of return sludge pumping was stepped up, sludge wasted 100 per cent to primary tanks to reduce solids in the aerators, and the air supply increased for 24 hours to 0.6

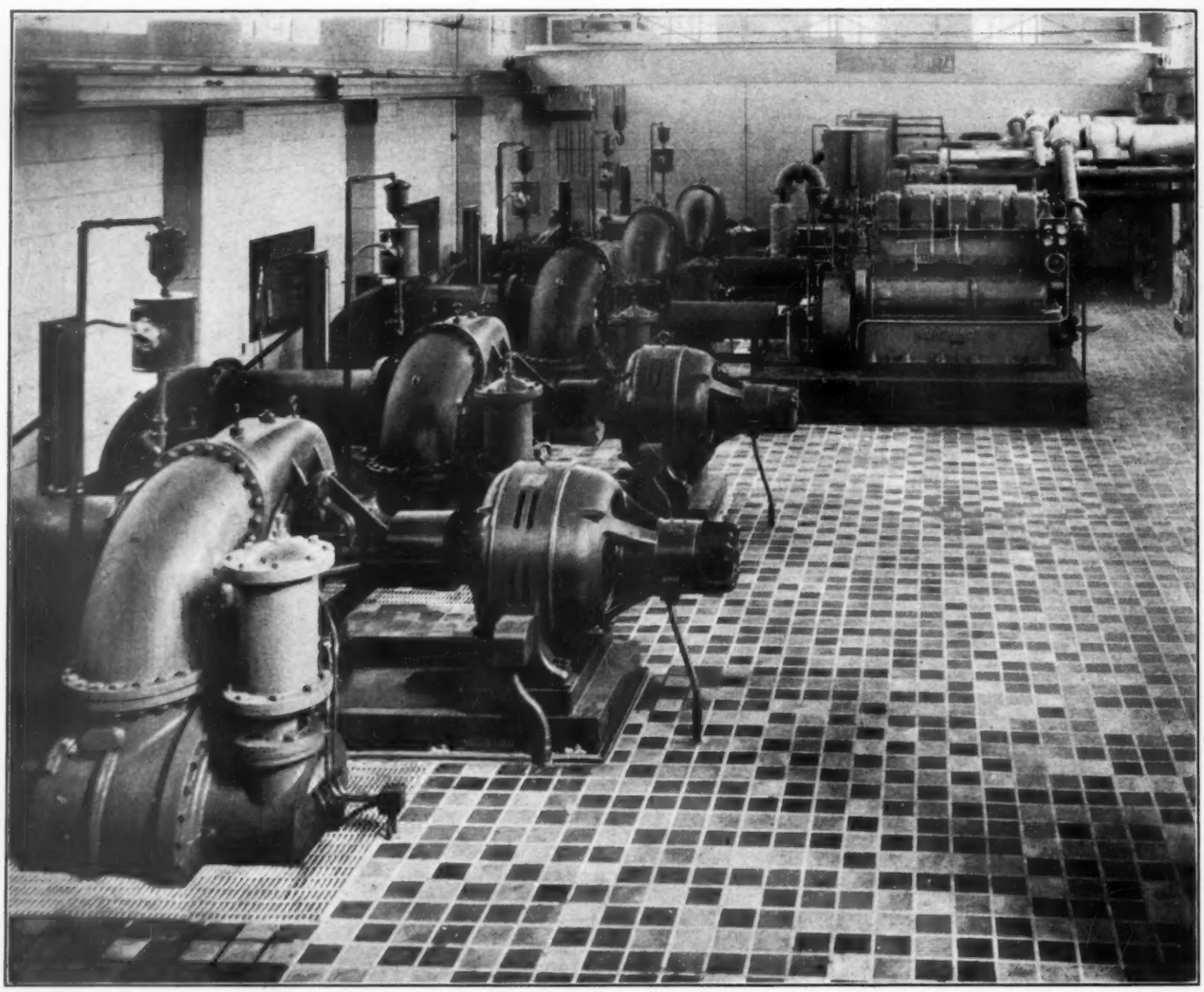
cu. ft. per gallon. The bulking did not spread to the other tanks and solids were dropped back to 600 p.p.m. and then built up to about 1,500 p.p.m. Normal operations were then resumed.

The usual procedure followed if the secondary effluent does not look quite as clear as usual is to waste slightly more sludge to the primary tanks and at times increase the rate of aeration. Bulking has not occurred enough yet to enable us to say positively at this time what steps will tend to correct it. It would appear, however, that the sewage treated at the Gary plant is of a character that does not cause the treatment process to be sensitive with bulking resulting from slight changes in the makeup of the sewage.

After observing the effect of various amounts of DO in the mixed liquor and in the final effluent and the appearance of the final effluent under different conditions, if bulking should occur, the first steps taken would be to reduce the suspended solids content of the mixed liquor, increase the rate of return sludge pumping, and increase the amount of air. With the flexibility and reserve available at Gary, all of these can be quickly accomplished.

During January, 1942, the sludge index (Standard Methods) increased sharply almost coincidental with a sharp drop in temperature. Operating routine was not changed prior to this time or during the period in question. The index went from a low of 106 to a high of 583. An index number of 583 would ordinarily indicate a bulking sludge with solids carrying over the weirs in the secondary clarifiers. It is evident that there was a swelling of the sludge, but on the day of highest index number the suspended solids reduction was 99 per cent and a 5 day B.O.D. reduction of 97 per cent. On this particular day the suspended solids in the raw sewage was 172 p.p.m. and the corresponding B.O.D. was 143 p.p.m., so that there was not a high initial total of either solids or B.O.D. to start with in computing percentage reductions. This high sludge index continued throughout the month for an average of 371; the solids and B.O.D. reductions for the month were 98.7 and 96.9 per cent, respectively. Nothing was done to try and reduce the index number and it has gradually receded to a low of 104 and a high of 382; in February suspended solids and B.O.D. reductions were 98.0 and 96.4 per cent.

Bulking sludge, as ordinarily recognized, is a sludge with a specific gravity so near that of water that the slightest current in a secondary settling tank will cause it to flow over the weirs. In the case noted



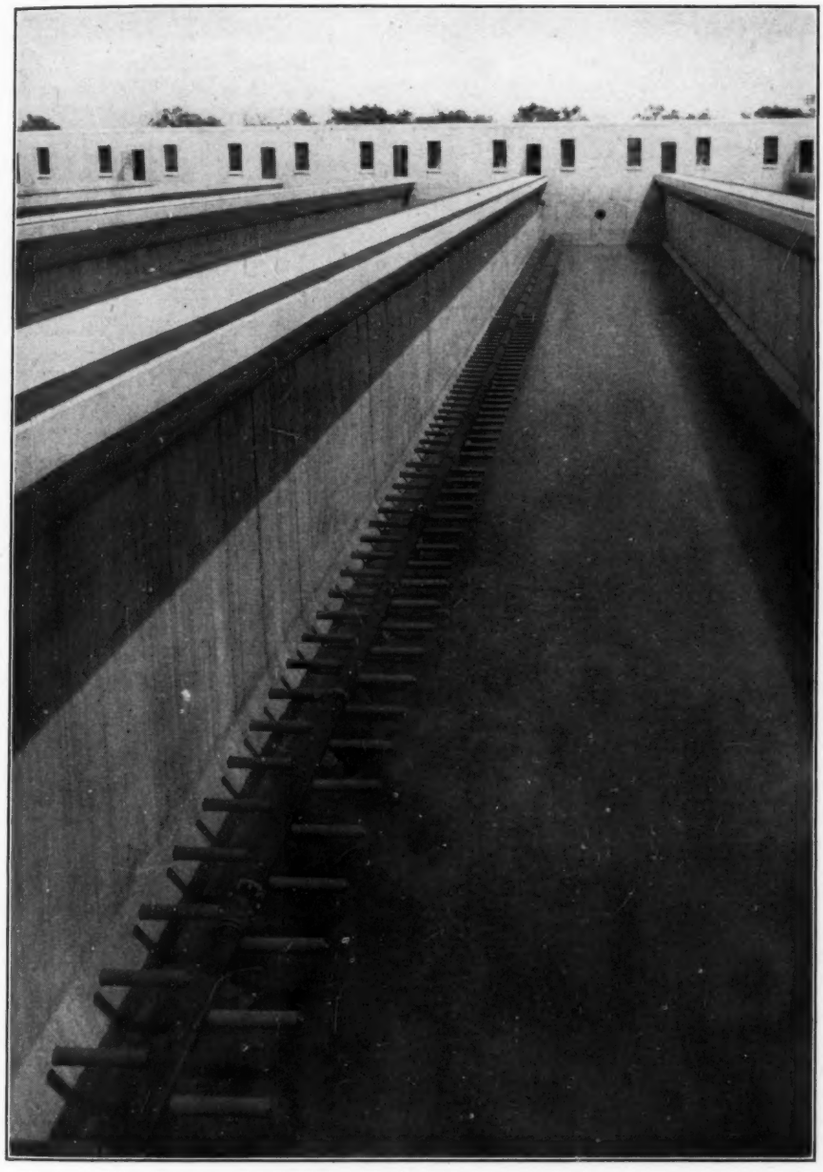
Blower Room

In foreground—Three Motor Driven Elliott Centrifugal Blowers of 5000, 7000 and 9000 C.F.M. capacities. In background—Two Roots-Connersville Blowers, of 7000 C.F.M. capacity each, direct driven by two 300 h.p. Cooper-Bessemer Gas Engines.

above, while the spacific gravity (not determined) was lower than in the month of November, with a sludge index which averaged 77 (range of 66 to 94), the sludge was still heavy enough to prevent its being carried over the weirs. Detention in the secondary clarifiers during the month of January was 3.44 hours, the settling rate 504 G.P.D. per sq. ft. and the overflow rate 7.3 G.P.M. per lin. ft. of weir. Undoubtedly these liberal capacities were reflected in the bulking experiment.

Return Sludge Pumping

The rate of return sludge pumping is maintained at as nearly a constant rate as possible which will give a return of from between 30 and 35 per cent. Any slight fluctuation in the daily percentages are due to variations of sewage flow. Waste sludge is returned to primary tanks when there is a build-up of solids in the aerators higher than it is thought desirable to carry. It is more convenient from an operating standpoint to waste at a fixed rate during part of a day only than to practice wasting continuously. At times no sludge will be wasted for two or three days. This intermittent wasting has no apparent effect on the efficiency of the treatment process as far as we have been able to observe to date. Return sludge pumps are Fairbanks, Morse & Company centrifugal motor driven type, with total capacity of 10,500 GPM.



One of the Aeration Units

Showing the method of staggering "Aloxite" Diffuser Tubes above the floor. These diffusers have proven their worth in regards ease of removal and cleaning.

Secondary Settling

There are 8 secondary settling tanks, 75 ft. square, designed to give a 2 hour retention period at a 40 MGD rate. Tanks are the Sifeed, radial flow type of Dorr Co. In order to prevent ice troubles during cold weather, all tanks have been operated during the winter months, giving a retention period of as high as 4.10 hours and an average for the year of 2.92 hours. The corresponding settling rate is 615 gallons per day per square foot. The design weir overflow rate is 60 ft. of weir per MGD of sewage. The long settling period (low flow through velocity) and liberal overflow weirs undoubtedly contribute towards maintaining a low solids content in the final effluent.

The following tabulation shows the consistency of the results:

Mo.	Ave. p.p.m. Suspended Solids in Effluent	Per Cent Suspended Solids Reduction Raw to Effluent
Jan.	26*	81.0*
Feb.	8	94.8
Mar.	10	95.2
Apr.	6	97.4
May	4	98.2
June	5	97.8
July	10	95.8
Aug.	2.4	98.7
Sept.	5.1	98.1
Oct.	5.6	97.7
Nov.	8.4	94.7
Dec.	12.2	96.8
Ave. for Yr.	10.4	95.52
Ave. excl. Jan. ...	7.0	96.8

*Affected by heavy oil discharged to sewers.

Sludge Digestion

Sludge digestion is in eight tanks, five primary and three secondary. The secondary tanks are equipped with floating gas holders of 60,000 cu. ft. capacity each. All tanks are 90 ft. in diameter with side depths of 20 ft. Primary tanks are heated and have concrete roofs. Temperatures are maintained as near 95 degrees F. as possible with the heat available from gas engine operation. Capacity of digesters is 6 cu. ft. per capita on the design basis of 170,000 population. Mixed crude and returned sludge is pumped from the primary clarifiers to the primary digesters in rotation, hours of pumping depending in general upon the amount of solids coming to the plant. After storms pumpage has been as much as 6 hours per shift per tank. Normally with average flow the pumpage will be about 2 hours per

Picturing the Excellence of Aeration and Evenness of Air Distribution from the Fixed Tubular Diffusers

shift per tank. In some instances sludge has also been pumped to secondary digesters in order to get rid of excess solids more rapidly.

No difficulty was experienced in starting sludge digestion. Ground water used to test tanks by the contractor having a pH of 7.3 stood at a depth of 5 ft. in the tanks when sludge pumping was started. Two digesters were filled first and heat at this time was supplied by a 300 H.P. gas engine driving a Roots-Connersville 7,000 C.F.M. blower operating on city gas. Lime was used to control pH and a total of 12,150 lbs. was used in conditioning the five primary digesters. Foaming did not occur at any time and the tanks finally stabilized at pH 7.1. This has varied slightly during the period of operation, dropping at time of excessive pumpage to pH 6.7 but no more lime was added at these times.

Supernatants overflow to the influent sewer. At Gary with efficient stage digestion the supernatants have not had any apparent effect on the treatment process. At times, after several months' operation without draining to sludge beds, the supernatants will show excessive amounts of solids due to both solids and temperature build-up in the secondary digesters. These solids are inert and carry a low B.O.D. Average B.O.D. and suspended solids content of supernatants from the three secondary digesters over a period of 8 months was 191 and 914, respectively, compared to 154 and 202 in the raw sewage. Quality of supernatants can be improved quickly by partial draining of secondary digesters and using final effluent to replace quantity drained to drying beds.

Gas Production

Gas production has exceeded expectations. Treating a domestic sewage from a tributary population of 100,000, an average daily production of approximately 100,000 cu. ft. would be all that would ordinarily be expected. Average daily production at Gary during 1941 was 146,156 cu. ft. Yearly averages for suspended solids and B.O.D. in the raw sewage were 207 and 152, respectively.

The following table shows the variation in gas production during the year.

Month	Daily Ave. c.f. of Gas	Ave. % Volatile Solids Raw Sludge	Digested Sludge	Ave. c.f. Gas Per # Vol.
Jan.	130,480	†	....	....
Feb.	165,700	69.0	....	10.3
Mar.	158,677	67.2	....	11.9
Apr.	156,600	†	54.0	....
May	159,000	†	56.0	....
June	134,650*	51.2	....	9.6
July	151,120	58.3	51.0	9.7
Aug.	155,600	57.5	....	8.6
Sept.	146,030	54.5	51.4	9.3
Oct.	144,400*	52.9	45.1	5.0
Nov.	119,107	55.1	41.0	8.2
Dec.	132,507	53.2	....	7.9
Average	146,156	....	....	8.9

*Excessive rainfall with "washouts" following.
†Muffle furnace out of commission.

With liberal gas production it was possible to furnish power for pumping 100 per cent for three months, over 99 per cent for two other months and over 96 per cent for another month. Over the remainder of the year the percentage of gas pumpage ranged from 44.5 to 73.6 per cent per month. For blower power there were 5 months at 100 per cent, 3 months over 97 per cent and 2 months over 90 per cent. The remaining two months were at rates of 87.1 and 89.1 per cent, respectively. Translating the above into value of commercial gas, based on a contract with the local utility, the amount used during the year would have cost $22,771.07. This visualizes the economy of installing equipment for producing and utilizing sludge gas in a way which the taxpayers quickly grasp.

Industrial Wastes

As noted earlier, there is only one industry that discharges what would ordinarily be termed objectionable industrial waste into the sewer system. This is a small steel plant located some five miles east of the treatment plant, which dumps approximately 29,000 gallons of acid pickling liquor per month.

The waste comes from tubs having capacities of 2,000, 3,000, and 6,000 gallons capacity each. These tubs are emptied at irregular intervals, but on the average one is dumped every three or four days. If the total quantity disposed of could be fed in the sewer system uniformly throughout the year the iron would average 4¼ p.p.m. Grab samples taken as the liquor passes through the plant shows total iron content as noted below. (These are approximate averages only and vary wth the rate of flow when dumping occurs and also with the size of tub dumped.) A drop in pH of from 7.2 to 6.9 in the raw sewage occurs as liquor passes through the plant.

Location of Sample	p.p.m. Iron
Raw Sewage	310
Clarified Sewage	160
Mixed Liquor	140
Final Effluent	85

The effect of the iron has been noticed through a gradual build-up in pressure on the blower system. This is not rapid, but takes place usually in from three to four months. With clean tubes the pressure is about 7 psi and when 8 psi is reached the tubes are cleaned with a 10 per cent solution of sulphuric acid.

The pickling liquor mixes thoroughly with the sewage in traveling to the plant, and four lateral interceptors dropping into the main sewer tend to give a thorough mixing. It is doubtful if this waste could be treated if the industry was located only a short distance up-sewer from the plant.

Summary of Operating and Analytical Data for 1941

Item	
Population Served	100,000
Average Daily Flow (M.G.D.)	19.37
Suspended Solids p.p.m.	
Raw	207
Clarified	109
Final Effluent	8
Suspended Solids Reduction Per Cent	96.11
5 Day B.O.D. p.p.m.	
Raw	152
Clarified	96
Final Effluent	9
5 Day B.O.D. Reduction Per Cent	94.31
Average Daily Gas Production Cubic Feet	146,156
Average Retention Periods. Hours	
Primary Clarification	2.06
Aeration Period	4.29
Secondary Settling	2.97
Average Sludge Index	86.4
Return Sludge Pumped, Per Cent	29.70
Average Solids in Mixed Liquor	1,557
Average Air Per Gallon of Sewage	0.52
Lbs. B.O.D. Removed Per 1000 CF Air	1.45
Air per Lb. of B.O.D. Removed	690
pH Raw Sewage	7.2
pH Clarified	7.2
pH Final Effluent	7.3
Operating Cost per Million Gallons	$ 9.16
Operating Cost per 1000 Lbs. B.O.D. Removed	$ 7.83
Operating Cost per Capita	$ 0.648

Aeration and Sewage Distribution Control Gallery

Operating Personnel

The operating force at the Main Plant at the present time is as follows:

1 Superintendent
1 Assistant Superintendent
1 Chief Chemist
1 Assistant Chemist
1 Clerk
1 Chief Operator
4 Pump and Blower House Operators
4 Outside Operators
2 Maintenance Men
2 Grounds Men
2 Laborers
1 Janitor

21 Total Employees

Additional temporary laborers will be required at times to clean sludge beds. One additional full time employee operates two sewage lift stations in the southern part of the city, and one of the employees from the Main Plant operates the Imhoff Trickling Filter Plant, and a small lift station nearby on one-half of his time.

Administration

The Gary Sanitary District was organized in 1938 under The Indiana Sanitary District Act of 1917. Administration is under a Board of Three Sanitary Commissioners. Present Board members are W. P. Cottingham, President (who is also City Engineer of Gary), Boyd E. Phelps, Vice President, and Otto V. Gray, Secretary.

References

(1) L. R. Howson, "Sewage Treatment at Gary," Sewage Works Journal, Nov., 1939.

(2) L. R. Howson, "The Plant That Steel Built," Sewage Works Engineering, Sept., 1940.

(3) John H. D. Blanke, "Garbage & Sewage Disposal at Gary," The International Engineer, Mar., 1941.

(4) Douglas Shearing, "Gary, Indiana, Modern Sewage Plant Uses Gas Engines," Diesel Progress January, 1942.

The effects of the sustained drought, sparcity of metering, and the consideration of what *may happen* to New York City's water supply are responsible for these warning posters being placed in every subway car in New York's vast system of underground railroads—for millions to take notice.

These posters, printed in conspicuous red, white and blue, read as follows:

The Result of Drought and War

YOUR WAR TIME DUTY
Water Shortage Acute

Conserve water *now* and avoid rationing later.

Repair all leaking fixtures *at once*.
Dept. of Water Supply, Gas and Electricity.

F. H. LaGuardia
Mayor

Patrick Quilty
Commissioner

GATE VALVES

Their Care and Maintenance

By ROGER W. ESTY
Superintendent
WATER AND SEWER BOARD
DANVERS, MASS.

TOO commonly, one of the most neglected of the routine operations in a water works system is the care and maintenance of gate valves. In some of the larger cities there are maintenance crews created particularly for this type of work. The crew is generally made up of some of the older men who are experienced in this work, due to their long service with the department or the water company.

They are furnished with a truck equipped with all the necessary tools, wrenches and spare parts, and they may also have built into the truck a mechanical operating device to open and close the gate valves. Smaller towns are more often than not unable to give proper attention to their gates, due primarily to lack of sufficient man-power to do this work and carry on the many other essential activities common to a water works plant.

My water works experience goes back over a period of 27 years. During that time I have located, measured and plotted onto cards and maps every hydrant, gate valve, and all of the pipe in our system. I have opened and closed every gate valve many times. It was 20 years ago that we first had a water waste survey made of our system and, as many know, this necessitates the opening and closing of essentially every gate valve in the system. This type of work we have continued every second year since, which affords added opportunities of locating and operating all of our gate valves.

Main Flushing Reveals Gate Valve Conditions

Occasionally our piping system is entirely flushed out, street by street, and this again means the operating of nearly every gate valve, and some have to be opened and closed several times during this flushing operation if properly conducted.

From this work experience is gained in the knowledge of what to expect of gate valves and the remedies that are used in perfecting their operation.

The Author

One of Our "Venerables"

We have been a going concern since 1876. It so happens that under this cover the gate is also an original.

As stated in the opening sentence of this article—all too commonly one of the most neglected of the routine operations in water supply systems is the matter of proper care and maintenance of gate valves. It is another case of "out of sight is out of mind." Because they are in sight and more apt to be used, fire-hydrants receives, on the whole, far more and better attention than do the underground "forgotten men" of the water works system.

Knowing Mr. Esty's views, experience and practices at Danvers in the care of valves and his motto—"KNOW YOUR GATE VALVES!"—he was prevailed upon to write this article.

Before the reader reaches the end of this contribution towards better water works operating practices we are sure that it will be agreed that we made no mistake in our selection of the author.

Stiff Operation a Main Trouble

One of the main difficulties, if not the main difficulty, we find with gate valves is that they turn hard. As years go on, if such valves are not operated occasionally they become more difficult to operate and in some cities and towns it takes two men, or even as many as four and six men, to close down a gate valve even during a testing period.

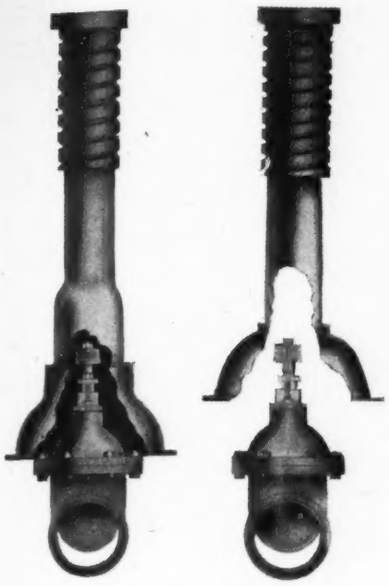
My experience does not go beyond a 20-inch gate valve, but it seems to me that the same principles and characteristics are applicable to all sizes.

A great deal of the indifference toward gate maintenance can be traced to the swivel chair operator. By that I mean the man in charge of the water works who has never experienced the opening and closing of all of the gate valves in his system. If he made tests of his system, such as a water waste survey, and had to work all night opening and closing these gate valves himself, he would soon issue an order to do something about making them operate easier. But generally, it is below his dignity to leave his swivel chair to do this type of work, to find out first hand the physical condition of his system. He doesn't care; he doesn't have to operate them; let the men do it, even if it does take two, four or six to do the job.

The Remedy

What are the difficulties we encounter; what causes them, and how can they be remedied? Why should it take four men to close a gate valve when one man should do it?

Why do stems get bent and broken? What is the cause of all this? Is it because the mechanism is not correct in design, or that the mechanism is not made heavy enough? I feel that the manufacturers as a general rule put on the market a gate valve that will meet all reasonable conditions according to our water works standard specifications. However, I do think the manufacturers do lose sight of one very important factor, and that fac-



Valve Box Settings

On the left is a setting as it is pictured in catalogs, and generally installed. To my way of thinking the method of putting the valve nut-up in the contracted section is improper. On the right is a suggested better way for the several reasons cited in the text. Possibly this may suggest an advantage to be gained in an improved design of this type of box to give better overall service.

tor is the packing, and in my opinion, if improper or neglected packing is not the direct cause, it is at least the seat of 90 per cent of all gate valve troubles.

Many ask, why does the packing have such an important bearing on the ease of operation of the gate valve. Well, the packing gets dry and hard as the years go on. This dry packing acts as a brake on the valve stem.

Take, for instance, your automobile—the brake linings are dry and the brake drum of the wheel is smooth and dry. When the pressure is exerted against one another it creates friction and this friction creates your braking or stopping power. Sometimes at high speeds this friction actually locks the wheels and causes fatal accidents.

On the other hand, pack the brake drums with grease and then attempt to stop your car. The grease eliminates the friction, therefore there is no friction created to stop your car.

Take a rope and wind it around an inch pipe three or four times and draw it tight and then attempt to turn the pipe. You will find you can't do it. Then grease the rope thoroughly and you will find that you can turn the pipe very easily. Try it for your own satisfaction.

Did you ever try holding an eel in your hand? If you have, you probably found that it was nearly impossible to hold it because it was so slippery. If you can get your gate valve stem and packing in the slippery condition you find the eel, you'll have no more hard turning gate valves.

However, there is a difference in the mechanism in some of the gate valves and one make may operate a little different than another make when new. But on the whole, modern gate valves should operate more or less in the same easy manner.

A Case of Proof

Several years ago, while making a water waste survey during nights, we came across a 12-inch gate most difficult to operate. It took the combined efforts of two of us to open and close the gate. The next day I had the gate dug up and repacked. It seems hardly believable, but it could then be turned with just one finger against the cross-bar of the gate key.

Such ease of operation surely saves breaking or bending the valve stems and makes the operation of the gate a pleasure instead of a dreaded job.

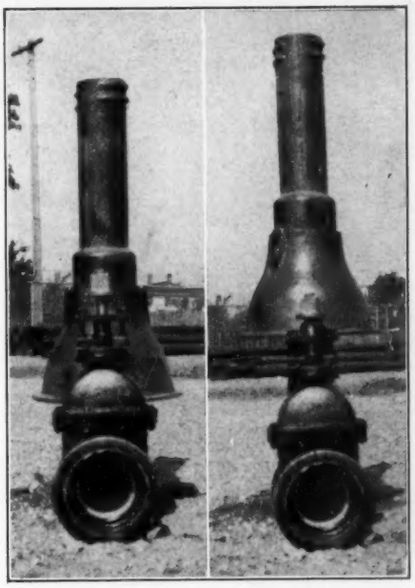
Some Packing Pointers

On many of our gate valves and nearly all of our hydrants we have removed the original braided packing and inserted a metallic plastic packing, with two or three strands of flax string type packing on top to keep it from squeezing out when the packing gland is tightened down.

After taking out all of the braided packing, we squirt down around the stem near the packing plate some kerosene or light lubricating oil. We then fill up the stuffing box with the metallic packing that comes in a loose plastic form or in string form. We then put on the stuffing box follower and tighten it down. We then open and close the valve a few turns and then tighten it some more. If it needs a little more packing we insert some and go through the operation again. This method has solved our packing problems and made hard turning gate valves easy turning, and makes fun out of a disagreeable job.

"And, a Child Shall Turn Them"

Our test of a properly packed and lubricated 20" gate is that a boy of 10 can close it at least half way. Behind this young "worker" is our oldest employee with 31 years of service.



A photographic attempt to indicate the advantage of setting the box bonnet higher, giving more clearance between box walls and nut and stem of the valve. The usual setting (left) is in truth a "rock trap," while the other permits rocks to pass by; also makes for easier key connection with the nut should the box become off-center.

The Larger Valves

In the large gates we drill a hole through the packing plate and insert an alemite fitting. These gate valves still have the braided packing in the packing box. By connecting a grease gun to this fitting we can apply by means of our air compressor about 3,500 pounds pressure and this forces the grease in and around the stem and packing and does a very satisfactory job of lubricating.

It does such a good job on these gate valves that it is a monotonous one man job of opening and closing the valve when testing; in fact, a boy 10 years old can operate the valve.

Large gate valves should have an ample size manhole constructed around them so that a man can get down to the gate and repack it.

Danver's Alemite Lubricating Outfit Servicing a Geared Valve.

Smaller gates can be handled more economically by using a 5¼ or 7-inch valve box over the gate with the cover flush with the road.

The gears of a geared gate should be enclosed in a housing with the gears running in oil. If the gears are not housed then they will collect rust and dirt in between the gears or teeth, making them fit tight and bind, causing the gate to operate hard. Dirt falling down into the hole when the cover is picked up causes some of this trouble.

We have eleven 20-inch open geared gates and we wish we had purchased the oil enclosed style. That surely was an error on our part, but our experience with them has taught us to advise others to buy the oil enclosed style.

We have constructed a shield that fits over the gears and the operating nut and fastens to the bolts holding the stuffing box to the bonnet of the gate. This has proved very satisfactory and the dirt does not get into the gears. This gives us the opportunity to keep them well greased.

Improper Valve Box Setting

Many gate valve catalogues show what, in my opinion and experience, is an improper method of setting the box over the gate. Pick up any catalogue and turn to the gate box section showing the 5¼ or 7-inch box. You will notice that the base or pot sets down over the top of the gate so that the base of the box is even with the flange in the center of the gate. Then the upper section, or middle section, is set onto the base, leaving the operating nut up in this section.

My contention of it being an improper setting and causing maintenance troubles is that if rocks do get into the boxes (and the kids sure do put them in sometimes), that the rock cannot go down past the operating nut. It gets wedged in so hard sometimes that it is impossible to get the key onto the operating nut, and if you do, you cannot turn it. If the box is pushed to one side slightly, the box then comes up against the operating nut and prevents putting the gate key onto the operating nut.

If, on the other hand, the base or pot is set so that the base is up at the level of the stuffing box plate, rocks then can roll to one side into the base, and if the box is tipped there is a greater possibility of getting the gate key onto the operating nut.

In my opinion, box setting is a very important part of your gate maintenance work.

Location Records

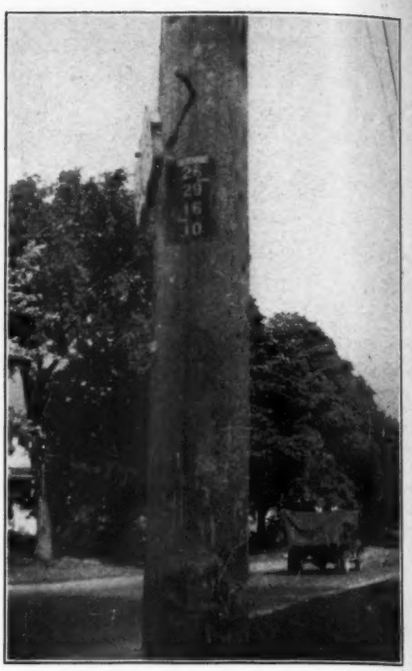
Location plans of gate valves should be carefully prepared and measurements should be taken from permanent benches, such as to other gate valves, hydrants, catch basin grates, manhole covers, curbs, etc., and not from telephone poles, trees, walls, fences, etc.

These measurements should be on cards and on sheets in bound books for quick reference. Each should have a number and these can be painted on the underneath side of the valve box cover if desired.

Stencilling of measurements onto buildings, poles, etc., are helpful for quick locating. Numbers can be nailed onto poles or buildings that will stay on as long as the pole or building remains in place. We paint a black square on the reference object and nail on the metal numbers that have been sprayed with an orange colored paint. The contrast makes it conspicuous from any other type of marking.

Removing Recalcitrant Box Covers

Sometimes the gate box cover gets sealed in with tar, or in the winter is frozen in. This can be very easily overcome by pouring a little gasoline on it and setting it on fire. In a few moments the cover can be easily removed.



Danvers Method of Marking Street Gate Locations

Yellow figures stenciled on black field on nearest pole.

Quite often it is found difficult to close the gate tightly. This is generally caused by tuberculation in the valve guides and seat. By opening and closing several times this incrustation breaks off and the velocity of the water between the gate and the seat of the valve will most always flush out, allowing the gates to eventually properly seat and closing off entirely the flow of water.

Gate valve work is not expensive. It is a tedious job but can be made very interesting by the various things that have to be done, such as checking measurements, marking poles or buildings, opening and closing, repacking, and the resetting of the gate box at higher elevation.

If a few of these suggestions are followed, most of your gate valve worries will be a thing of the past:

Good plans and measurements.

Stencilled or metallic reference numbers on poles, buildings, etc.

Gate box covers flush with the surface of the ground.

The base of the box well above the center flange of the valve.

Opening and closing each valve on a yearly schedule.

Last, and the most important, proper packing and lubrication.

And a good motto is:

"More turning of gate stems and less of swivel chair stems." "Know your gate valves!"

HYDRANT MAINTENANCE

By E. T. CRANCH
President and Manager
NEW ROCHELLE WATER CO.
NEW ROCHELLE, N. Y.

GOOD housekeeping is alwals essential. Women are judged by the manner in which they keep their homes—neatness if you please. Neatness in water works operation should also be considered essential, and perhaps we should ask for the ladies' advice on our water works "housekeeping" more often than we do.

The Hydrant as a Symbol

Fire hydrants are, without doubt, the most conspicuous and most frequently commented on part of any water works plant. Yet too often these symbols of the water utility suffer from neglect. In the good old days when one could tour the country without worrying about gasoline and tires it was always refreshing to come to a town with bright, freshly painted hydrants, and these always stood out in sharp contrast to the many communities where the hydrants were drab and neglected. We in the water works fraternity should practice "good housekeeping" for our satisfaction as well as for the impression it makes on others.

Paying Procedure

Twice each year every fire hydrant should be given a routine inspection —once in the spring and once in the fall. This inspection should include a pressure test. This test is important for three reasons: It checks on the closing of the drip valve, it reveals any cracks which may have developed from either freezing or external damage, and it proves whether the nozzles are tight. When you first apply the pressure test always stand back of the hydrant. We have seen serious injury caused by a nozzle flying off and striking a man in the stomach.

Outside of the condition of the hydrant, the pressure test also at times gives valuable information as to underground leaks. The pressure observed should always be compared with that recorded on previous tests. If there is any material reduction the matter should be at once investigated. This method has sometimes given the first clue to locating serious underground leakage.

The Author

The author of this article has a penchant for practicing what he preaches in the way of "good housekeeping" and in particular the efficient maintenance of hydrants. For a number of years successful as superintendent and manager, shortly before writing this request article was made president of the New Rochelle Water Co. This election, however, does not change his status as general manager other than to strengthen it.

Importance of Lateral Valves And Their Maintenance

Every hydrant should be equipped with a gate valve on the lateral. This is essential to the effcient operation of any water works system. Otherwise a damaged hydrant may necessitate the shutting down of a considerable length of street main and the putting out of service of several other hydrants while repairs are being made to one. This might easily prove very embarrassing to a water department as well as a water company, especially if a hydrant is damaged during a large fire. If any municipality still has hydrants without a gate valve on the lateral we strongly recommend that such gate valves be installed at the first opportunity they can be obtained.

Report Records

Figure 1 is a form of daily report for work on hydrants which we have found very satisfactory. It will be noted that this form calls for "No. of Hyd." We have found it convenient to number all of our hydrants serially. This number is stenciled at the base of the hydrant on the side facing the street. Figures about 2 inches high are used. It will be noted that following the pressure column ("Press.") there is a column "Time Taken." In comparing pressures it has been found helpful to know the time of day at which each pressure was taken. The next five columns are simply checked off as the operations are performed. In the last column any unusual repairs required are noted.

Painting Policy and Practice

We have found it good policy to paint all hydrants once a year. In this way the hydrants always have a well groomed look and are a credit to the company. If a high grade enamel paint is used the hydrant may look quite passable for a period of two years but at the end of two years it is difficult to apply a new coat of enamel satisfactorily without a lot of wire brushing on the old coat. We have found a semigloss paint to be most satisfactory. It holds up very well for a year and is easy to repaint. We have painted as many as 140 hydrants with one gallon of paint.

Immediately after a hydrant is painted, be sure a "wet paint" sign is securely fastened to the hydrant. It is surprising how much clothing can be damaged by brushing up against a freshly painted hydrant, and unless the wet paint sign is there, the water utility (company or department) will be faced with paying damages.

We have tried using a portable spray pump but have found it wasteful of paint and that we could paint just as many hydrants per day by hand.

Packing and Lubrication

For packing we use jute impregnated with tallow. This has proven very satisfactory. For lubrication we use a grease with a graphite base. We have tried various types of grease and the graphite base grease is the only one we have found which will not cause the caps to stick, especially in cold weather.

Cap Chains Useless Impedimenta

The common practice is to have the caps fastened by chains to the hydrant barrels. We found the fire departments in trying to get con-

THE NEW ROCHELLE WATER CO.,
NEW ROCHELLE DIVISION
New Rochelle, N. Y. .....19.....

DAILY HYDRANT REPORT

No. of Hyd.	STREET	Press.	Time Taken	Greased	Packed	New Bolts	Painted	Numbered	Unusual Repairs

FORM 6 1M-4-37

Fig. 1.—Daily Hydrant Report Form Used for Recording Routine Maintenance Inspection and Repairs.

A dependable worker given a thoroughly equipped truck for hydrant and valve maintenance work represents money well spent.

B.P. 13640

NO.

LENGTH OF LATERAL ft.

HIGHWAY ☐
PRIVATE ☐

DIAM. OF LATERAL in. CUTLETS

SMITH TAP ☐
REG. VALVE ☐

DISTANCE HYD. TO VALVE

DIAM. OF STREET MAIN in. HYD. BBL. SIZE in.

ELEVATION ft. DATE

REMARKS

DATE	PRESSURE AT INSPECTION	DATE	PRESSURE AT INSPECTION

DATE	HYDRANT		PIPE		VALVE SIZE	G.B. OR M.H.	WORK ORDER
	MAKE	VALVE SIZE	SIZE	LENGTH			

NO.

TYPIST PLEASE NOTE—THIS SCALE CORRESPONDS TO TYPEWRITER (PICA) SCALE—SET PAPER GUIDES SO THAT CARD SCALE WILL REGISTER WITH MACHINE SCALE WHEN CARD IS TURNED INTO WRITING POSITION. START INDEX THREE (3) POINTS FROM LEFT EDGE OF CARD. USE OTHER POINTS OF SCALE FOR OTHER DIVISIONS OF VISIBLE TITLE. SET TABULATORS TO INSURE PERFECT ALIGNMENT OF EACH DIVISION OF INFORMATION. FOLD BACK OR REMOVE STUB AFTER TYPING. USE NEW TYPEWRITER RIBBON.

KARDEX VISIBLE DIVISION 886-200-85814-'38 REMINGTON RAND INC.—13 Printed in U.S.A.

Fig. 2.—Permanent Maintenance Record Form of the Kardex System.

(Gives all essential operating information at a glance. Also provides the important continuing property record now increasingly demanded by State Public Service Commission.)

nected to a hydrant in a hurry were often greatly annoyed by the chain. We therefore tried the experiment some ten years ago of removing all the chains. We feared that caps might get lost or misplaced during a fire so we equipped each fire truck with an extra cap, but to date none of these extra caps have been used and the fire departments are greatly pleased with the elimination of the chains.

It is essential at all times to have the full cooperation of the fire department and arrangements should be made to have the fire department report to the water department after it has used any hydrant. The water department should then make a special inspection of this hydrant to see that everything about it is all right. The fire department should also be instructed never to force a hydrant in trying to close it. If it does not close readily, have the water department or company notified.

Continuing Records

Figure 2 illustrates a form of permanent hydrant record which is used in a Kardex file. This card gives all the essential operating information as well as that necessary for the maintenance of a continuing property record such as is required now by several Public Service Commissions.

WATER AND SEWAGE PATENTS

(Of Recent Issue)

Reported by
JULIAN F. SMITH*
CENTRAL COLLEGE
FAYETTE, MO.

Water Patents

Tile Pipe Joint. Chas. E. Bennett. U. S. 2,280,183, April 21. A floating joint for tile pipe has a resilient gasket sealing the annular space between the members of a bell and spigot type joint.

Deacidifying Water. E. L. and Lucie E. Holmes and Wm. G. Prescott (to Permutit Co.). U. S. 2,281,194, April 28. Neutralizing free acid in water by contact with a large area of resin-impregnated material, the resin being formed by condensing an amine with an aldehyde.

Boiler Compound. E. L. Smead and S. S. Sadtler (to Societa Anonima Henex). U. S. 2,281,392, April 28. Pressing the juice from agave pulp, fermenting it and neutralizing the product with alkali to make a boiler compound.

Zeolites. J. R. Bates (to Houdry Process Corp.). U. S. 2,283,172-3-4, May 19. Preparing synthetc contact masses by precipitating a zeolite in solid or gel from sodium silicate and a compound of an amphoteric metal; reducing the alkali metal content of zeolites below 1 per cent by base exchange; anl calcining zeolite pellets above 900° C.

Locating Water Strata. Geo. H. Ennis (one-half to Robert V. Funk). U. S. 2,283,429, May 19. Determining the location of water inlets into a well by the light transmitting properties of a charge of substance distributed in the well.

Sewage Patents

Treating Sludge. Royal W. Gelder (to Paul Bechtner). U. S. 2,281,759, May 5. Dispersing a floc of hydrated colloidal clay particles through sewage sludge and dewatering the treated sludge.

Flow Control. Thos. R. Camp. U. S. 2,281,826, May 5. Liquid flow control apparatus having a settling channel for deposition of solid particles, and a discharge control weir comprising a pair of vertical walls the distance of which from each other is adjustable.

Treating Pulp Mill Effluent. H. O. V. Bergström and Karl G. Trobeck. U. S. 2,282,112, May 5. Volatilizing impurities from pulp mill waste liquor by contact with a gas, while controlling frothing with an alkaline earth hydroxide or carbonate.

Sewage Stabilizer. C. G. Hawley (to Hawley Engineering Corp.). U. S. 2,282,225, May 5. Stabilizing sewage in apparatus which exposes a spray of sewage to a whirling air current in a confined space.

Treating Sewage. Walter E. Buell and Leon A. Winter. U. S. 2,283,166, May 19. Feeding sewage to a trickling filter at a constant rate interrupted by rest intervals which are timed to defined proportions.

Sewage Meter. Richard Bennett. U. S. 2,283,906, May 26. Metering sewage by passing it through a pipe and odofoce plate so that its pressure can be measured.

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*Associate Director, Hooker Scientific Library.

ARKANSAS WATER AND SEWAGE CONFERENCE WELL ATTENDED

IN SPITE of difficulties due to the war and possibly because of a recognition of the increased importance of the water works man's job because of the war, the Twelfth Annual Arkansas Water and Sewage Conference held a most successful meeting April 13-15 at the University of Arkansas in Fayetteville, Ark.

Six of those attending had the distinction of not having missed any of the twelve meetings since organization of the Conference.

Demonstrations Featured

Demonstrations held on Tuesday afternoon, consisting of tests of meters, pumps and the making of fire hydrant flow tests were made in or near the Engineering Building and demonstrations of algae and of chemical and bacteriological tests in the Chemistry Building, attracted more than usual interest. The round table discussion led by L. A. Jackson, Little Rock, on Wednesday morning was also worthy of special mention. The following subjects were presented: "Sterilizing New Pipes," E. F. Byerly, West Helena; "Locating a Small Leak," Henry George, Fayetteville; "Locating a Lost Pipe Line or Manhole," W. G. Check, Gravette; "Thawing Frozen Service Lines," R. E. Wages, Springdale; "Emergency Repairs," A. H. Ullrich, Ft. Smith.

Distinguished Alumnus

This Conference was particularly fortunate in the presence of Dr. J. E. Gibson, Manager and Engineer of the Commission of Public Works of Charleston, S. C. Dr. Gibson is a past president and honorary member of the A.W.W.A., a graduate of the University of Arkansas and a recipient of the honorary degree (Dr. Eng.) from this University. He gave an interesting illustrated address at the banquet.

New Officers

Fletcher Thompson, Clarksville, was elected a member of the Arkansas Operator Licensing Board to take the place of Edward A. Leverett, Conway, deceased.

The following officers were unanimously elected:

Chairman: W. A. Mayhan, Little Rock.

Vice-Chairman: E. F. Byerly, West Helena.

Secretary: Harrison Hale, Fayetteville.

Executive Committee: W. R. Spencer, Fayetteville; Edgar Brown, Fayetteville; John Harris, Forrest City; C. A. Williams, Helena; W. G. Check, Gravette; Frank Lewis, Mena; Lon Embree, Magnolia.

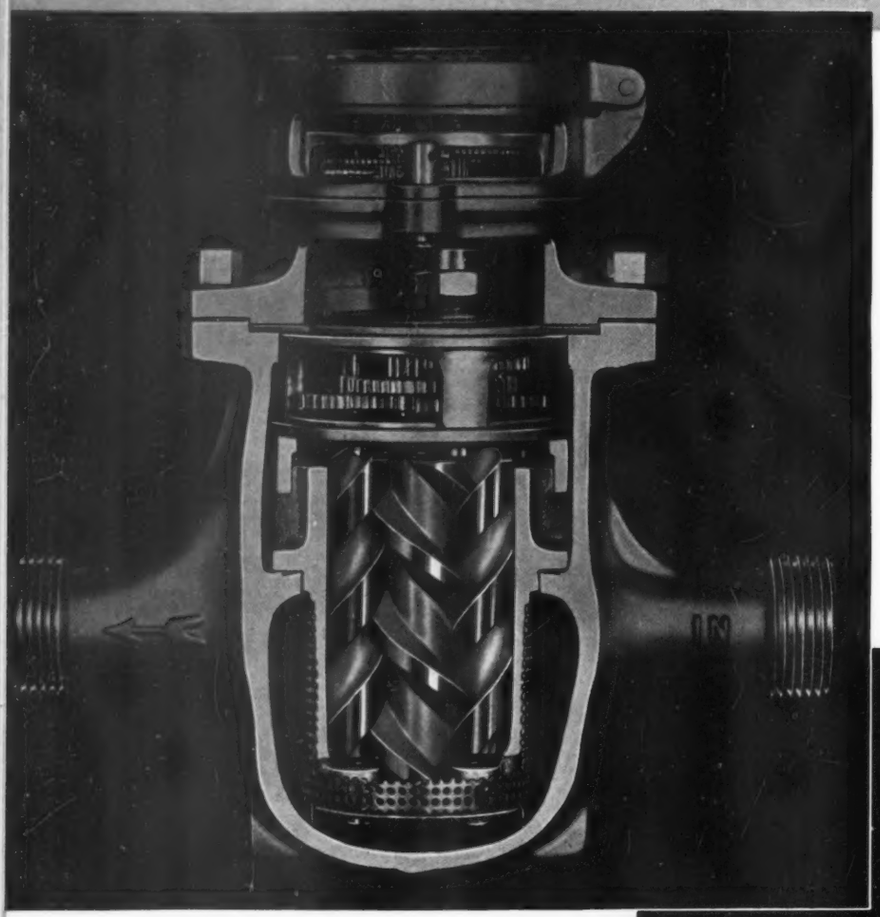
Prior to the opening of the Conference, examinations, held by the Voluntary Licensing Board, were taken by a large number. An increasing interest in this work has been in evidence.

Most of Those Attending the 12th Annual Arkansas Water and Sewage Conference

Orchids . . .

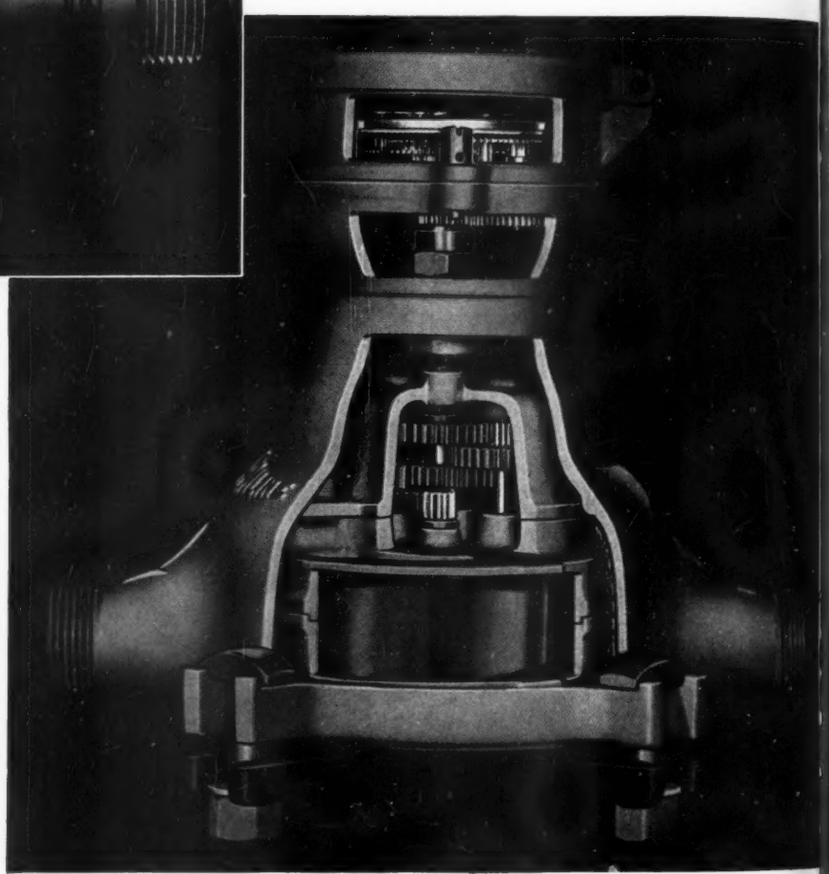
to the Research Men, Engineers, Salesmen and Progressive Water Meter Buyers . . . all of whom have helped to make Pittsburgh Imo and Empire Streeemline the outstanding meter successes of the century

Like Orchids – TOPS IN THEIR FIELD



PITTSBURGH IMO METER

The Pittsburgh IMO Meter is of the screw propulsion, positive displacement type. The operating mechanism consists of three screws called rotors, which mesh with each other and fit the bore of the measuring chamber. Water enters the measuring chamber from the bottom and as it is forced upwards by line pressure, causes the rotors to turn from its path. The threads of the rotors act as a continuous piston, always moving in a forward direction. The revolutions of the center rotor are transmitted to the register through an enclosed gear train where they are converted into units of measurement.



Empire STREEEMLINE METER

The Empire Streeemline is of the oscillating piston displacement type. The measuring chamber is cylindrical with a division plate separating the inlet and outlet ports. The balanced piston, slotted to clear the division plate, is also cylindrical, with horizontal web carrying a post in the center. Below the web, the post guides the piston around a roller in the lower abutment well. Above the web the post drives an arm by which its motions are transmitted through the enclosed gear train to the register. The piston itself does not rotate, but glides or oscillates back and forth with its motion controlled by a piston pilot—always moving in the direction of flow.

PITTSBURGH-NATIONAL METERS

THE MOST COMPLETE LINE OF WATER METERS IN THE WORLD

PITTSBURGH EQUITABLE METER COMPANY

NEW YORK · BROOKLYN · DES MOINES · MEMPHIS · OAKLAND · TULSA · CHICAGO · BOSTON

MERCO NORDSTROM VALVE COMPANY
Main Offices, Pittsburgh, Pa.

NATIONAL METER DIVISION, Brooklyn, N. Y.

KANSAS CITY · PHILADELPHIA · SAN FRANCISCO · LOS ANGELES · SEATTLE · HOUSTON · COLUMBIA · BUFFALO

A NEW "PHILADELPHIA STORY"

Or, How a Systematic Water Waste Survey in Progress Has Already Saved Philadelphia a Needed 13,000,000 Gallons Daily to Meet Defense Demands

By MARTIN J. McLAUGHLIN
Chief
BUREAU OF WATER
PHILADELPHIA, PA.

DURING the recent depression Philadelphia found herself, in common with most other municipalities, in straitened financial circumstances. Demands upon the water works system instead of increasing began to decrease and the need for making additions to the system ceased to exist. But with this contraction in use there was also a decrease in revenue and many improvements, and even items of maintenance had to be deferred. At length, in 1939, a committee of experts was appointed to investigate the water works system for the purpose of recommending improvements necessary to bring it into first class operating condition. A bond issue of $18,000,000 was voted to pay for these improvements and engineers from the office of Morris Knowles of Pittsburgh, Pa., were employed to supervise the expenditure of this money.

However, the design of the needed additions would in itself consume considerable time and it seemed desirable to relieve the load on the system as much and as quickly as possible. During the years from 1926 to 1931 The Pitometer Co. had been employed to make a Pitometer Water Waste Survey of the system. The results of that survey were most gratifying. Underground leakage of about 35,000,000 gallons per day had been located and repaired. House waste of approximately 50,000,000 gallons per day had been stopped and industrial meter under-registration of approximately 4,750,000 had been corrected.

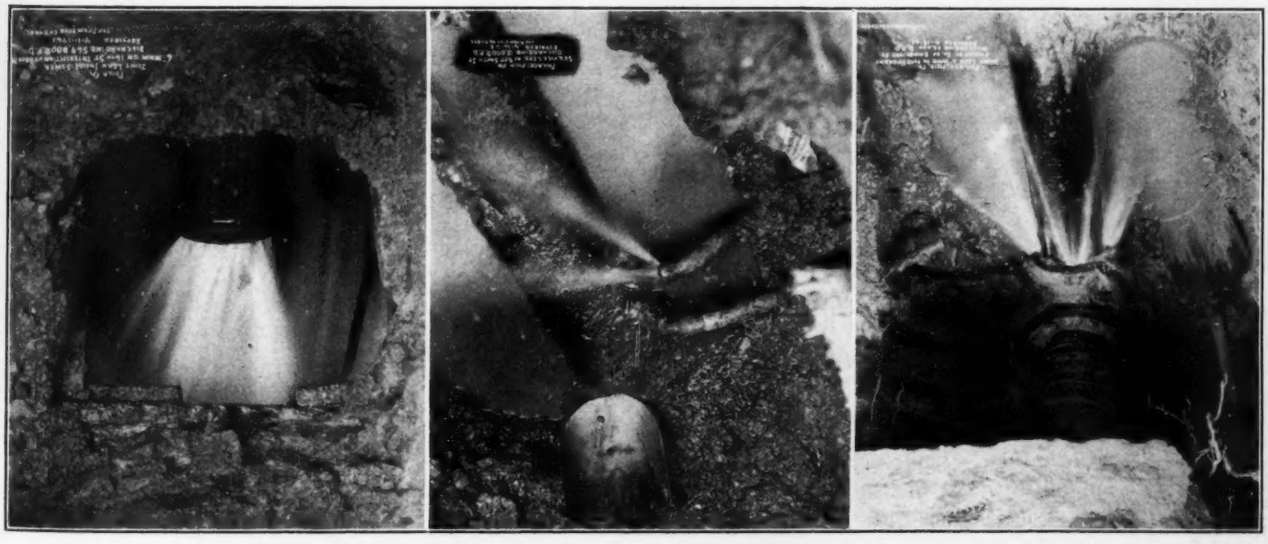
Waste Reduction First Logical Step

With a definite knowledge of the possibilities of conserving the available water supply by the elimination of the underground leakage which undoubtedly had developed since the previous survey, the city decided to again contract with The Pitometer Co. to make another Water Waste Survey of the distribution system, and arrangements were made with the WPA to furnish most of the labor in connection with the operation. To date all of West Philadelphia has been surveyed and the survey of that section of the city lying to the south of Callowhill St. is approaching completion. An additional contract has recently been entered into covering a section of the city lying along the Delaware River northeast of the central part of the city.

How the Survey Is Conducted

The survey is conducted in the following manner:

The district which is to be tested, and which includes an average of 8 miles of distribution main, is segregated by valve operation and all but one or two feeds in this district are shut off. Recording Pitometers are installed on these feed lines through 1 in. corporation cocks and the flow into the district measured for a twenty-four hour period. Indirect measurements are then made at night to determine the distribution of the night rate of flow in small one or two block "shut-outs." Manifestly where little or no flow exists at night there can be no leakage, but where the measurements show appreciable flows after midnight in-



Some of Our "Philadelphia Story"

The effect of traffic on a 6" fire hydrant joint—25,000 g.p.d.

A typical service leak of which there were many—15,000 g.p.d.

This 6" main, actually in a sewer, was discharging 569,000 g.p.d.

More Typical Exhibits

A cracked 12" main shooting away 455,000 g.p.d.

A 6" main carrying the weight of another failed for 50,000 g.p.d.

A good trick if it only worked. A sewer manhole found resting on a 6" main cost 100,000 g.p.d.

vestigations are made to determine the cause of the high flow. The actual location of the leak is determined by the use of sound intensifying instruments in the hands of engineers who have become proficient in this particular line of work through years of experience. It is very seldom that the leak is not located within the limits of the first excavation made for its repair.

Since the inauguration in 1940 of the defense program, the demand for water upon the Philadelphia water works system began to increase and had continued to increase as more and more industries turn to the manufacture of war material. All the water saved to date, by the elimination of underground leakage, has been made available for use by the war industries without further taxing the capacity of the existing system. That the savings to date have been of considerable assistance is evident from an analysis of the findings.

The Most Important Sources of Waste

The largest single source of waste so far discovered has been leakage from the cast iron mains themselves, broken mains, split mains, and blown joints. A number from each source has been found. Up to date, 62 leaks of this kind have been located wasting a total of 4,369,000 gallons per day. In almost every case these breaks were caused by underground conditions, such as the construction of masonry structures by other utilities in such a way that a bearing load was placed upon the cast iron main. Several examples of leaks caused by this loading of the mains are shown in illustrations accompanying this article.

Next in importance based on the average size of the individual leak, though not in total waste, is the waste from leaking abandoned services. As is to be expected, leaks on dead services will average greater losses than leaks on live services because after a leak on a live service becomes large enough to affect the pressure, the consumer complains and the leak is repaired, but an abandoned or uncompleted service can become completely severed without being discovered unless the water finds its way to the surface. So far, 127 abandoned services have been found leaking, a total of 2,273,000 gallons per day.

There have also been located a large number of leaking services in use, and it is surprising to note how much water can escape each day from a leak in an ordinary domestic service before the pressure is affected to such an extent that the customer complains. A total of 373 live services have so far been found to be leaking 2,754,000 gallons per day.

Six miscellaneous leaks not included under any of the above headings were found to be wasting 146,000 gallons per day.

Under-Registration of Large Meters an Important Item

One feature of the survey, not previously mentioned, is the testing in place of industrial meters on 4 in. and larger services. Increased revenue resulting from the repair of defective meters discovered in this manner has been considerable. A total daily under-registration of 3,060,000 gallons has been discovered to date. Not all of this has been reflected in increased sales as a very large percentage of this amount was found on the meters supplying a semi-charitable consumer. As the result of these findings this consumer greatly reduced its consumption of water so that the benefit to the department was in the nature of decreased consumption rather than increased revenue.

Altogether, a total of 13,000,000 gallons per day has been saved so far. About 40 per cent of the city has been covered and it is hoped and believed that savings will continue at about the same rate as the survey is extended into other parts of the city. Some idea as to how valuable a saving of 13,000,000 gallons per day is, can be visualized when we realize that it is enough water to supply an average American city of 130,000 persons with all the domestic and industrial water normally used. In this city, about a ton and a half of coal is required to pump a million gallons of water, so that the indicated savings from this one item are about 7,000 tons, or 150 freight cars annually. Aside from the cost this is a distinct contribution to the war effort by the relief it affords our over-burdened railroads. There have been additional savings of power, chemicals, etc. While Philadelphia uses very little chlorine, when compared to most cities, it is still true that the savings of a million gallons of water per day results in the saving of approximately a ton of chlorine per year. Although the money value of the twelve or thirteen tons saved each year is not large it is a distinct contribution to the war effort as it conserves a critical material.

A By-Product of the Survey

A by-product of the survey has been the location of closed and defective valves and many valves have been found in each category. The

closed valves were opened and the defective ones repaired. This has not only put us in a better shape to make shut downs for routine repairs, but has also improved our ability to quickly cut out sections where mains may at some future time be broken as the result of enemy bombing.

Although the financial savings to the city have been more than enough to justify the survey, the greatest present benefit has been the relief which it affords to our water system, heavily loaded as it is with war demands. We realize its full value when we contemplate the effect of adding to our present demand the necessity for filtering, pumping, and distributing an additional 13,000,000 gallons of water per day. This is equivalent to the construction of a pumping station, filtration plant and transmission main of sufficient capacity to supply 13,000,000 gallons per day.

Due to the difficulty in obtaining priorities and the inability to secure the necessary materials, the water works improvement program has of necessity been materially slowed up, and it is questionable whether or not the benefits from this program will be felt in time to assist in the present emergency. It can, therefore, be seen how essential it is to conserve every available gallon of water in the City of Philadelphia, by the elimination of all sources of waste, such as is being done by the Pitometer Water Waste Survey now in progress.

FUME TRAP FOR DIESELS

(And Other Internal Combustion Engines)

By DON C. CALDERWOOD
Engineer
PENNICHUCK WATER WORKS CO.
NASHUA, N. H.

IN THE engine rooms which house Deisel engines there is usually a problem of fumes, in some cases to such an extent that even with all the windows open these fumes cause smarting of the eyes and throat irritation. These fumes, for the most part, originate in the crankcase of the engine and usually find their way into the engine room through the crankcase breather pipe. This problem is particularly acute in installations which have worn or stuck piston rings because the highly compressed vapors in the cylinders blow by the rings, producing a back pressure in the crankcase. This back pressure in turn forces the oil vapor and fumes out through the breather pipe.

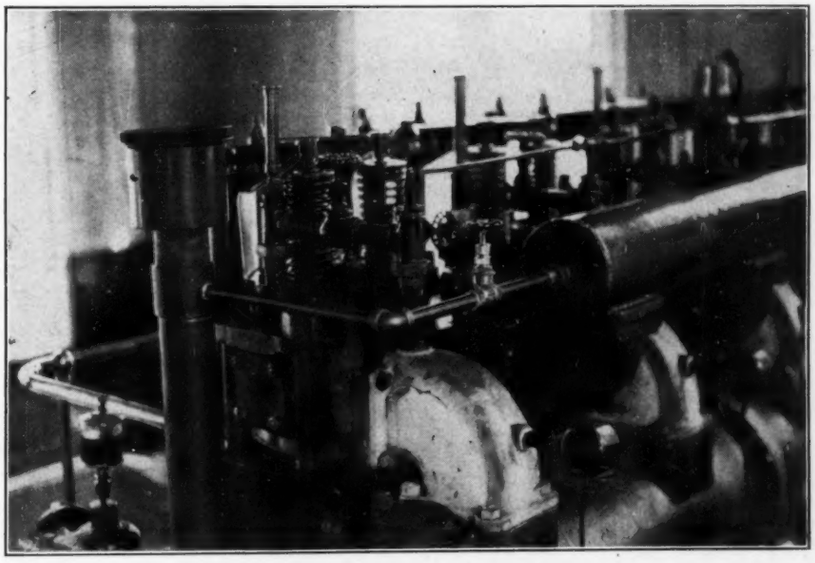
All this trouble can be eliminated by a simple piping job. Drill and tap both the air-intake manifold and the breather pipe for ½ inch pipe. In many installations it makes a much easier and better looking connection if the breather pipe is extended so that both connections can be made at the same level. Connect with a ½ inch pipe, putting a gate valve in the line, as shown in the accompanying picture.

After making the piping changes, start the engine, first *making sure that the ½ inch valve in the new connection is closed.* When the engine is well warmed up, open the gate valve slowly until the suction obtained through the connection to the intake manifold overcomes the back pressure in the crankcase. A simple way to determine when this pressure is equalized is to blow smoke by the end of the breather pipe; if the smoke is slowly forced away from the end of the breather pipe, open the valve a little more; if the smoke is drawn into the breather pipe more than can hardly be detected, close the valve a little more. It usually takes a little patience to obtain just the right opening of the valve, so when this is obtained, tighten the packing nut on the valve with a wrench so that the vibration of the engine will not change the correct adjustment.

Caution—Considerable care should be taken in adjusting this valve opening, making doubly sure that it is not open too wide. If this valve is open more than necessary, the lubricating oil vapors in the crankcase will be drawn into the cylinders and burned as fuel; this in turn will cause high lubricating oil consumption.

With this connection you are not only freed from the fumes which formerly gave you much discomfort, but you are actually burning and obtaining power from them, but remember that as a fuel, fuel oil is always cheaper than lubricating oil, so watch the valve setting for economy sake.

This type of connection is not confined to Diesels alone since it can be used on any internal combustion engine.



Fume Take-off Line on Diesel Engine
Suction on Crank-Case Breather Pipe from Intake Manifold Is Adjusted by Setting of Valve in the One-Half Inch Line.

SERVICE SHOOTING

Wherein "A Friend Is Made When a Corroded Service Is Saved"

By LA VERNE TRENTLAGE
Assistant Superintendent
WATER DEPARTMENT, ELGIN, ILL.

IN THE West Section of Elgin the well water supply was very hard and corrosive.

After many years of gradual build-up, hundreds of services became "plugged." As a department we did not have to look for these, for when this time arrived and consumers realized they had practically no volume, they would enter the Water Office and say, "We have no pressure—can hardly get any water."

In scores of complaints it was revealed that it was impossible to get water on the second floor, especially when water was being drawn on the ground floor. One who has never experienced this annoying trouble simply cannot appreciate their plight.

The average services, as mentioned, do not deliver more than 1 G.P.M. with our normal main pressure of 50 pounds behind it.

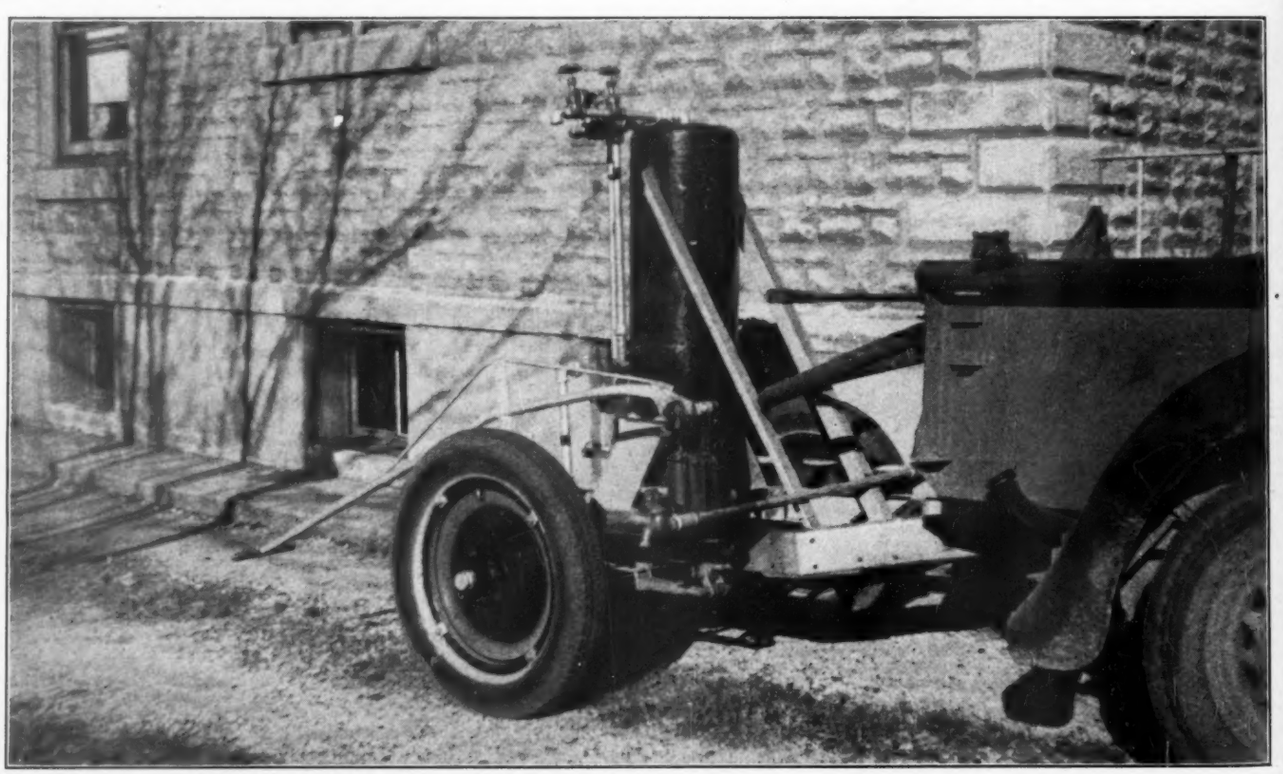
The Author

There is no doubt in my mind but that thousands of small residential services are being replaced annually due to this corrosive condition. However, since we now know what we can do to restore much of the original volume, we feel obligated to the consumer to help him. We do this job of clearing the service line gratis because we are serving the public as a non-profit institution. Of course, it would be the simplest thing to say to this particular group of sufferers, "We are very sorry, but you will need a new service." To date we only use that statement after we *know* we cannot help them.

Step by Step Procedure

Our method of procedure to correct this fault is as follows:

1. First; a check is made to make certain of no break in the service-line itself. If O. K., then:
2. A 2-gallon can is filled from the cold water faucet in the kitchen and the "time" to fill is taken by a stop watch and recorded.
3. Immediately after, we take an ordinary ¾-inch garden hose, with the nozzle on, to learn the farthest point the water can be delivered. Then with the nozzle off we learn the farthest point the water can be delivered. We make this type of test to gain some technical but concrete



The Elgin "Blow-Tank."

Demonstrating That the "Medicine" Was Good.

Measuring the 20-ft. nozzle throw "before" and throwing a 46-ft. stream "after" at main pressure of 35 lbs. The record showed that the 2-gal. measuring can filled from the kitchen faucet in 20 seconds after the shot as compared to 2 min., 5 sec. time for filling before the shot.

figures for the record. Also the consumer can readily see what has been accomplished when the job is completed.

4. The blow tank is then hooked up and we're off. (How the blow is made follows later.)

5. After completing the job, points 2 and 3 (above) are followed up in the same way for the sake of comparisons.

Pertinent Facts

Now, and very briefly, we shall bring out some interesting facts drawn from our experience in "blowing."

1. Each "shot" discharged from tank into service is a mixture of air and water under 1,400 pounds of presssure—released by a quick opening valve.

2. The 1,400 pounds is necessary to obtain the excellent results that we get.

3. In very obstinate cases we also dig up at the curb box, connect on the tank, then blow out to main. Results? . . . Very satisfactory.

4. Only one service in a hundred is ruptured in the shooting.

5. It is advisable to blow only single lines—not forked.

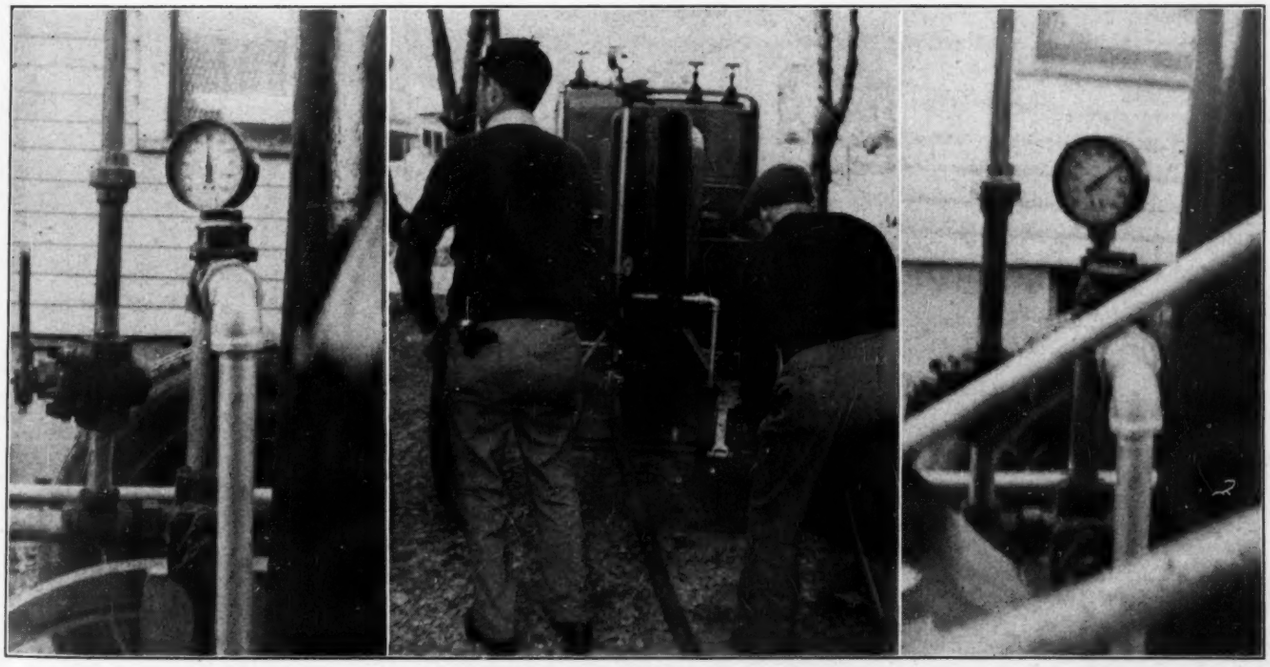
6. Services up through 1 inch can effectively be "blown."

7. Consumer signs a release, which protects the Water Department in event any pipes or the service are damaged.

8. Time required to make the blow . . . one hour. (Three men best for the job.)

9. Seven out of ten services are effectively cleaned out by the blowing method.

It is the kitchen faucet or sprinkling that usually tell the consumer about the poor volume. We all agree that when we want water we want it



1,000 lbs.—And Still Pumping—1,400 lbs.
(And Ready for the Shot.)

right now, in big volume and plenty of pressure.

We attack this problem in two ways: (1) Technical and (2) Practical.

For instance:

Before blowing we learn that it requires two minutes to fill a two-gallow can at kitchen sink.

After blowing we learn that it requires only 20 seconds to fill the same can . . . timed. These facts are entered on a record card.

Before blowing, outside, we learn that a nozzled hose will force water only 10 feet. (Without nozzle, ¼ to 2 inches only.)

After blowing, between 40 and 50 feet with nozzle, and from 9 to 22 inches without nozzle. These, of course, are measured figures.

The average housewife is not concerned about minutes, seconds, or measured distances "technically." Only "practically" is she satisfied when bigger volume, more pressure, and ability to sprinkle her neighbor or wet down the shingles on the roof is present.

Some Added Revenue Results

As a side-light on this subject, it was learned from a detailed study of 100 services that the consumption per address per quarter increased only an average of 5,250 gallons, or an increase in the water bill of $1.50 per quarter.

The Department's reaction was neither disappointment nor surprise, for our chief concern was to satisfy the consumer by increasing the volume of water at the "Time and Location" demanded.

Parallel in importance to the results obtained by blowing is the financial side from the consumer's angle. For instance—

If we were not able to help the situation, the consumer would have to invest $35.00 or more for a new service.

This expenditure they already visioned, and as a result they all are very appreciative of our efforts. Therefore we know that:

"A FRIEND IS MADE EVERY TIME A SERVICE IS SAVED."

Since our water has been softened and filtered, the number of poor pressure complaints has fallen off 80 per cent and we anticipate a further reduction again this year.

Blowing Operations

In closing, I want to give a brief description of the direct method employed.

The Blow-Tank stands outside. The meter is disconnected and the tank hose connected where the meter was. The shortest length of hose possible is used.

The tank of atmospheric air is allowed to fill up to "Main Pressure" with water from the mains. From this point, and on up to 1,400 pounds, the pressure is developed by means of an hydraulic pump (single piston) operated manually. When 1,400 pounds is reached, the "shot" is discharged by means of a quick-opening lubricated valve.

A small gate valve is then opened after each shot, to allow the fresh water from the "main" to push out the "disturbed" water in the service back to, but by-passed from tank so it will discharge onto the ground.

After every "shot" the water, upon returning, will run red or very dirty for about five or ten seconds. Usually, when water clears up, it is proof that our job is done.

Several check valves are distributed about the Blow Tank, this tank being A.S.M.E. tested for 3,300 pounds.

For a plumber to attempt to obtain the results we do with an instrument has proven a failure. Releasing air in "Jackrabbit jabs" is also a failure. . . . It is that terrific impact that does the work.

When a service is partially obstructed by a soft deposit, one "shot" will restore the original efficiency.

Our results are so satisfactory, I doubt we will ever install an X-Ray machine to satisfy those who may wonder what takes place inside the service during blowing, or what it looks like after the "blow."

The 5 x 8 inch record card here reproduced reveals the story of a typical blowing operation. On the reverse side is the record of time required for the 2 gallon can filling from the consumer's kitchen faucet "Before and After" administering the "medicine."

ADDRESS 402 Wilson DATE 11-18 1941

WATER SERVICE - LINE INFORMATION

(1) PRESSURE ON MAIN (35#)
Length of Service (49')
Make of Service (Lead)
Age of Service (4 years) (45)
Size of Service (¾")

(2) BUILDING
Blown for {Dirty Water ( ) / Poor Pressure (✓)
Size of Meter (¾)
Size of Building ( )
Size of Pipe Throughout ( )

(3) 1. CONDITIONS BEFORE BLOWING
Vol. Del. from ¾" Hose (¾")
Vol. Del. from ¼" Hose with Nozzle (20')

2. CONDITIONS AFTER BLOWING
Vol. Del. from ¼" Hose with Nozzle (46')

(4) COND. AFTER BLOWING FROM METER OPENING TO MAIN
Vol. Del. from Hose After:
1st Blow (9") (1400) + Pressure
2nd Blow (11¼") ( ) + Pressure
3rd Blow ( ) ( ) + Pressure
4th Blow ( )
5th Blow ( )
6th Blow ( )
Length of Hose { Long ☐ Med. ☒ Short ☐

(5) RESULTS Color ( )
Vol. ( )

(6) FROM CURB COCK TO MAIN
No. Times ( )
Results ( )

(7) HOUSE SERVICE CONDITIONS
(a) Vol. ( )
(b) Cause {Corrosion ( ) / Pipe Too Small ( )

FINAL RESULTS
( )
By ( )

Record Card Kept.

On the rear of this 5x8-in. card appears this information:

Time Required at Kitchen Faucet to Fill 2-Gallon Can.

Before Blowing	After Blowing
(2 min., 5 sec.)	(20 sec.)

Johnson Becomes Head of Erie Water Dept.

Papesch Made Asst. Supt.

J. D. Johnson

By unanimous vote the City Council of Erie, Pa., agreed on the recommendation of Mayor Barber that Asst. Supt. John D. Johnson be made General Superintendent of the Erie Water Department as successor to the late "Jim" Dunwoody.

To fill the Asst. Supts.' position, George Papesch was promoted from his position as Chemist and Supt. of Filtration. To the latter position Robert A. Blair has been appointed.

Mr. Johnson, a native son of Erie, is 49 years old. He has served the Water Dept. for better than 35 years. At 14 he went to work in the Department, appropriately enough, as water boy. Five years thereafter he was foreman. In World War No. 1 he served with the U. S. Engineers in France and returned to Erie in 1919 to be made Assistant Supt.

DRILLING AND DEVELOPING DEEP WELLS

By J. ARTHUR CARR

Superintendent of Water

RIDGEWOOD, N. J.

WHILE some of the ideas expressed in this article are applicable to wells of all types, they are offered chiefly from experiences in the construction of wells in the red sandstone formation, such as is encountered in Northern New Jersey.

In the writer's opinion, the most important points in the construction of a new well are:

1. Full and complete specifications and a bid sheet permitting a fair comparison of prices.
2. The selection of a qualified contractor.
3. A full-size hole that is plumb.
4. Proper sealing.
5. Proper and complete testing.

(1) Specifications and Bid Sheet

The preparation of specifications is not as simple a matter as it may appear if the interests of both the purchaser and contractor are to be safeguarded. There are several points both in the specifications and bid sheet which, unless they are carefully covered, may cause difficulty in deciding the low bidder and create misunderstanding in making payments.

Usually the most expensive portion of the well is the portion which is cased down from the surface and into rock. Frequently the depth into rock to which the casing will be carried cannot be determined in advance. In order that all bids may be considered on a comparable basis, it is recommended that a statement be made in the specifications similar to the following: "For the purpose of comparing bids, the distance from ground surface to rock will be considered to be .. feet," the distance mentioned being the approximate depth the rock is believed to be.

The depth to which a well is to be drilled is also frequently difficult to state beforehand. So that bids may be comparable, a statement such as follows is advisable: "While the contractor's bid is based upon a maximum depth of .. feet, it is understood that drilling may be stopped at any depth by the engineer; however, it is guaranteed that the contractor shall be paid for at least .. feet of drilled well."

The Author

The author of this article has for several years served as co-chairman with Jas. A. Harding of the A.W.W.A. Committee on Deep Wells and Deep Well Pumping.

In recognition of his fruitful work as committee leader, Mr. Carr this year was voted the George W. Fuller Award for conspicuous services to the water works profession.

The cost of at least one test should be included in the bid price. In addition, the specifications should stipulate the amount to be paid for any additional testing which may be required. This amount is usually set up on an hourly basis.

(2) Selection of Drilling Contractor

Next in importance, after bids are properly filed and evaluated, is the selection of a skilled and experienced contractor. The contractor selected should be one who is not only financially responsible, but more important, one who knows how and has the equipment to do a first class job and also the desire to do it. In this connection, a method which embraces the prequalification of bidders is desirable.

Full and accurate records are most essential for the proper future operations of a well. There should be absolute insistence that the contractor keep and turn over to the owner detailed information as to what is being done and what is happening as the work progresses. Samples of drillings at various depths should be preserved and the location of any change in formation noted.

(3) A Plumb and Full Sized Hole

It is poor economy to drill holes that are likely to later prove too small. The hole should be started of sufficient size to permit as many reductions in diameter as may be necessary and still have ample diameter for the installation of a pump of high efficiency.

During construction, a well should be plumbed and gauged at frequent intervals in order that the purchaser may be assured a straight and plumb hole of full required diameter. Watching the cable to see that it hangs in the center of the hole is a rough check for plumbness. Bit diameters should also be frequently checked.

While a hole that is straight, although slightly out of plumb, does not interfere to any great extent with a pump setting, a zigzag or corkscrew hole, or one with flat spots or constrictions in diameter, may cause much trouble and expense.

(4) Proper Well Sealing

In the writer's opinion, there is only one sure and permanent method of sealing a rock well to shut off surface or top ground water, and that is by double-casing and cement filling the annular space between the two casings. The inner casing may be installed either before or after completion of drilling and should extend well past all soft or broken formation near the surface of the rock. If the inner casing is placed before the completion of drilling, care should be taken to avoid jarring and cracking the cement during subsequent drilling operations.

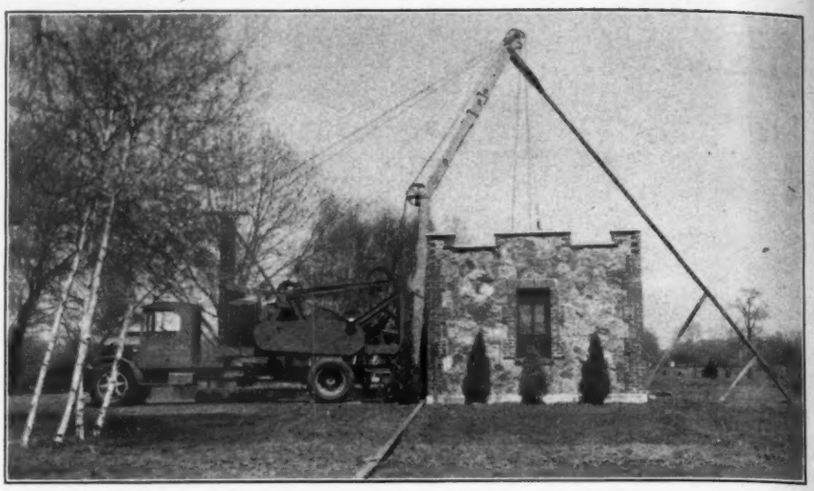
Considerable care should also be exercised in placing the cement to avoid bridging and to entirely fill the space between casings. In placing the cement, the method most frequently used is to pipe the cement slurry all the way to the bottom of

the space to be grouted. Grout should always be applied as one continuous operation.

(5) Testing

Tests should be made with a pump of sufficient capacity to handle more water than it is expected the well will produce and with the pump set at a lower level than the maximum anticipated draw down. This should be done so that the maximum yield and the yield at different draw down levels may be determined.

Opinions as to the duration of tests vary. The writer favors 72 hour tests of continuous pumping, especially in new well fields or where there is a possibility of interference with other wells. For 60 hours the well is pumped at maximum capacity and draw down. Usually after the first 24 hours a point is found where the well stabilizes and the level does not change. The well is then pumped at that level until the 60th hour. The pumping rate is then gradually reduced at intervals of about 1 hour and the draw down at different capacities noted. By this method a good record of the capacity of the well at different draw down levels is obtained. From this data the most economical pumping level may be selected—a matter of considerable importance when considering the day-after-day costs of operation.



Deep Rock Well Development, May, 1942, Ridgewood N. J.

Here is seen the machine developed to work over the tops of existing well houses. This development work on these rock wells improved yields from 50 to 200 per cent—something heretofore not considered possible.

Some Notes on Developments

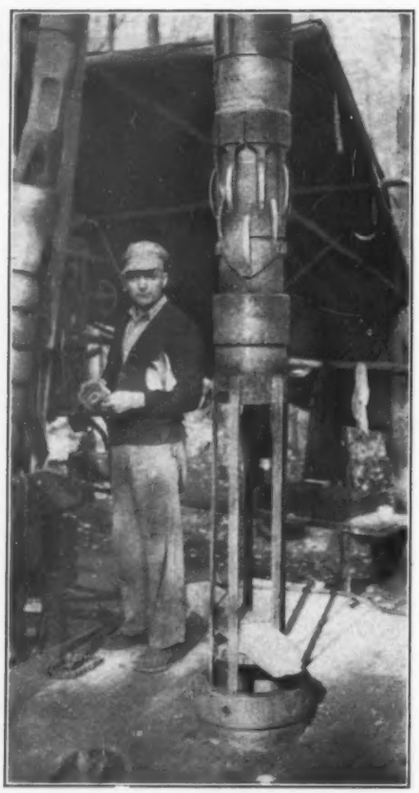
In the paragraph relative to plumbness and size, mention was made of development. In the past it has generally been accepted that when the drilling of a rock hole is completed, nothing further can be done to increase the yield. From his experiences in Ridgewood during the past two years, the writer is convinced that the odds in favor of increasing the yield in rock wells can be bettered by application of some of the methods of development heretofore used only in the development of sand and gravel wells.

During 1940 two Ridgewood wells were developed, using the conventional valve type surge plunger such as is used in sand wells. The capacity of one well was increased 30 per cent and that of the other well 200 per cent.

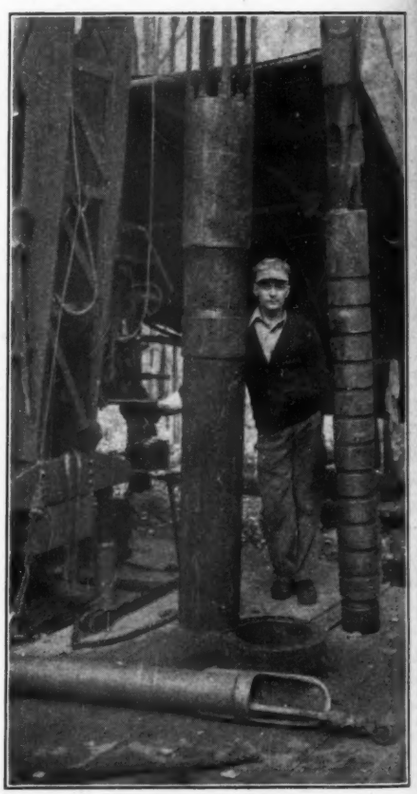
In the course of agitation of those wells, many cubic feet of sand, clay and pieces of rock were brought into the well. Along with the other material were many small pieces of cement which seemed to indicate that practically all of the action due to agitation was taking place immediately below the casing. This seemed to indicate that better results would be obtained if the effects of agitation could be spread over the entire well wall.

With that thought in mind, a steel cage-like structure 30 feet long with a temporary seal at top and bottom was constructed. This device was then suspended on a string of pipe and lowered to the bottom of the next well constructed. The well was then developed for several days, using a long, heavy, steel plunger in place of the conventional one. The packers were raised at varying intervals of time until the well wall had been exposed to agitation for its full depth. This method of development was used on four wells during 1941 and the capacity of all was increased, the amount of increase ranging from 50 to 200 per cent.

Early in 1942 development was applied to a well built in 1932. This well was producing 80 GPM at a pumping level of 120 feet. After development the well is producing 170 GPM at the same level.



View of the Top of the Double Packer Used in the Surge Treatment.



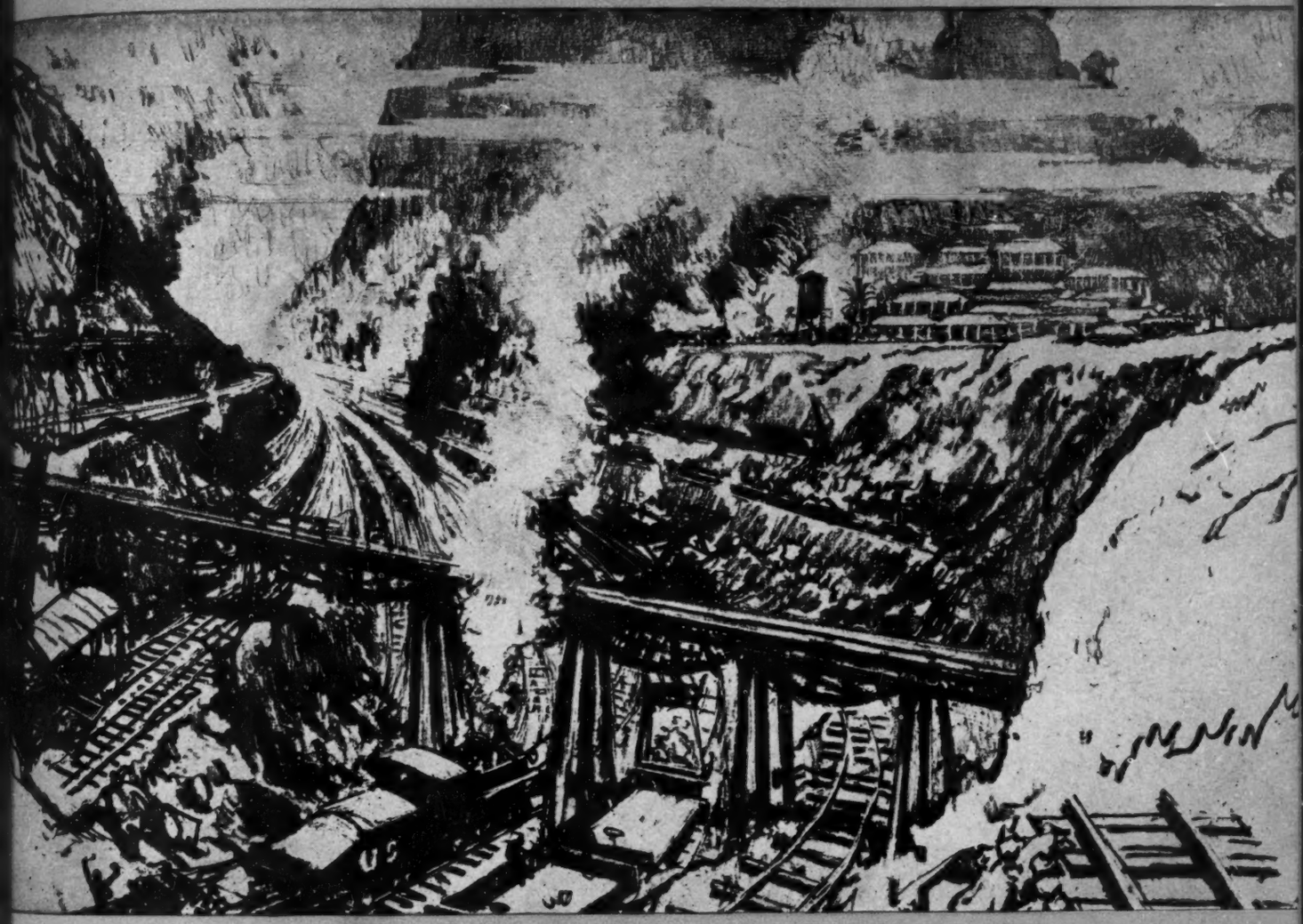
Lower Section of the Double Packer and the Agitator Used.

HAD THE PURPOSE been merely to unite two great bodies of water, the Panama Canal in all probability would never have been built. Instead, it was the dream of far-sighted men to achieve a new and greater service for the commerce of man by building this waterway that would join the Atlantic and the Pacific Oceans.

Similarly, two companies, each great in its own right, may enlarge their usefulness by establishing a union between their respective enterprises.

A TESTAMENT TO PROGRESS AND SERVICE...

"THE CUT AT PARAISO." LITHOGRAPH BY JOSEPH PENNELL. REPRODUCED BY PERMISSION OF THE LIBRARY OF CONGRESS WASHINGTON, D. C.



With the Niagara Alkali Company, the Electro Bleaching Gas Company has now been combined to form a single, but larger institution in the fields of chemical manufacture and research.

The Niagara Alkali Company pledges to sustain the high quality and integrity of the products of its manufacture as heretofore. At the same time, the Niagara Alkali Company will be able to extend to old customers the new and greater service that is made possible by broadened facilities, expanded resources, and experience.

Niagara
ALKALI COMPANY
60 EAST 42nd STREET, NEW YORK, N. Y.

CAUSTIC POTASH · CAUSTIC SODA
PARA · CARBONATE OF POTASH
Liquid Chlorine

EBG NIAGARA ALKALI COMPANY

CANADIAN SECTION TURNS OUT STRONG

For Meeting Where Roar of Water Power Is Heard Louder than Anywhere in the World

WITH an attendance of 370 or better, the Canadian Section of A.W.W.A. held its three day annual meeting April 15-17 in Niagara Falls, Ontario, where the power of WATER is nowhere else in the world so impressively felt.

Chairmen

(Retiring)
William Storrie
Consulting Engr.
Toronto

(Incoming)
O. H. Scott
Manager Utilities
Belleville, Ont.

Although the registered attendance did not constitute a new record for the Canadian Section, the turnout of 352 members and guests at the annual banquet to hear the Honorable Humphrey Mitchell, M.P. and cabinet member, deliver the keynote address did constitute a new record —and there proved to be a reason.

Mr. Mitchell, as Canada's new Minister of Labor, without wasted words evinced the sincerity of the Minister as the type of leader who will collectively win this war in short order if we can produce several more like him. He pointed out that mass production and engineering achievement is the answer to winning the war, and that the war can be won on the American continent. To do so with the least loss of life and in the quickest time, he reminded all that more and more sacrifices on the home front was amongst the first essentials for victory in the shortest time. It was a grand speech, deserving of the roaring applause at the finish—more for the calibre and sincerity of the speaker than for the words spoken. Along with those of the Canadians, our hats are off to you and your kind, Mr. Humphrey Mitchell.

"Open House" a New Feature

The most novel feature of the convention was the idea of the Canadian Water Equipment Manufacturers Assn. in trying out a new entertainment arrangement which involved the holding of "Open House" by the manufacturers collectively in place of the previous custom of so-called room entertainment conducted by member firms individually and somewhat competitively. The scheme proved a great success—so much to the liking of active members that a request was made that the manufacturers repeat this method of providing divertissement and conviviality.

The scheme involved the establishment of what was designated "The Water Works Club" in a spacious tavern room just off the hotel lobby. Here refreshments (both soft and hard) were served to all comers during those hours between technical sessions and evening functions and thereafter until the official closing hour agreed to by the manufacturers and the Section's Executive Committee in advance. In the "Water Works Club," which some persisted in labeling "The Bar," there flowed music, good cheer, and much conversation. There was the place to find everybody during leisure hours in-

Prof. R. W. Angus
Univ. Toronto
Toronto
(Voted Fuller Award)

J. Clark Keith
Mgr. Utilities
Windsor Ont.
(Director A.W.W.A.)

stead of trying a dozen or so hotel rooms. The whole thing seemed a marked success and worthy of repetition.

Awards and Honors

At the annual banquet the following awards and presentations were made:

To Professor Robert William Angus, of the University of Toronto, went the George W. Fuller Memorial Award "for his wise leadership and promotion of water works practice"; in particular for his noteworthy contributions to research in water hammer and leadership qualities as professor of mechanical engineering. The presentation was made by

Secretaries

(Of the Section)
A. E. Berry
Chief Engr.
Ont. Dept. of Health
Toronto

(Equipment Assn.)
"Jim" Kinney
Manager
W & T Co. Ltd.
Toronto

the President of A.W.W.A., Louis R. Howson.

To George G. Routledge, Supt. of Water Distribution for Toronto, went the Hunt Memorial Award of the Canadian Section.

A new custom was then introduced in the nature of presentation of "Membership Service Certificates" to the longest standing members of the Association. Those who received certificates showing membership of 30 to 35 years duration were:

R. J. Smith, Mgr. of Utilities, Perth, Ont.

Thos. Hodkinson, Supt. of Water, London, Ont.

(Mr. Smith, the oldest living member, joined in 1911, and Mr. Hodkinson in 1913.)

Certificates also went for corporate memberships of more than 30 years' standing to the cities of London, Peterboro and St. Thomas Ont., the oldest being London—1909.

Certificates to members of 25 to 30 years' standing went to:

Robt. W. Angus, Toronto.
Ross L. Dobbin, Peterboro.
Roland C. Harris, Toronto.
Theo. J. Lafreniere, Montreal.
McH. McCrady, Montreal.
Wm. McDonald, Ottawa.
Adrien Plamondon, Montreal.
Walter M. Scott, Winnipeg.
Wm. Storrie, Toronto.
Chas. Warder, Niagara Falls.

Utilities Commission of Brantford.

"The Canadian Engineer," Toronto.

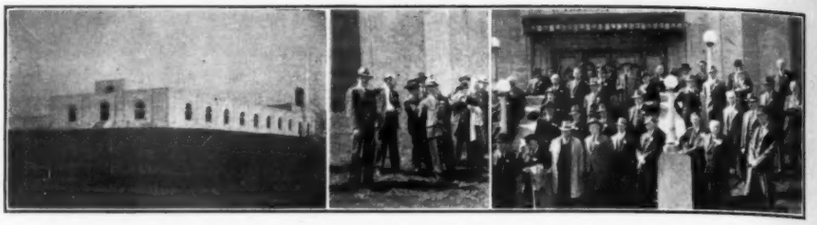
Certificates were also issued to those members of 20 to 25 and 15 to 20 years' standing. The lists are too long to print, however.

The customary Retiring Chairman's Cane was presented to Mr. Storrie, and the Past Chairman's Certificate was delivered to Geo. H. Strickland of Windsor, 1940 chairman.

A Memorial Certificate went to the family of the late Francis Porter Adams, former City Engineer and Manager of Utilities at Brantford and a past chairman of the Section. The very splendid memorial was drawn and read by Wm. C. Miller of St. Thomas, also a past chairman.

Entertainment

In addition to the "Water Works Club," the manufacturers provided an exceptionally good floor show following the banquet and the ladies were given a Bridge Tea and Theater Party the first evening while the men were "clubbing" and being entertained with movies.



Niagara Falls (Ontario) Filter Plant and Pumping Station and Group That Inspected It

(Interesting was the design of the barbed-wire barrier fencing enclosing the plant. One armed guard was on duty. We took pictures of the tricky wire enclosure but do not feel it would be "cricket" to publish it, since the negative was not "declared" when persuading the Customs Agent to pass the undeveloped films.)

Officers Elected

The following were recommended as officers for the ensuing year:

Chairman

O. H. Scott, Mgr., Public Utilities Commission, Belleville, Ont.

(The Section does not elect a Vice Chairman.)

New Trustees for 3 Year Term

Geo. H. Ferguson, Chief Sanitary Engineer, Department of National Health, Ottawa.

W. H. Waddell, City Engineer, Owen Sound, Ont.

The continuing Trustees are:

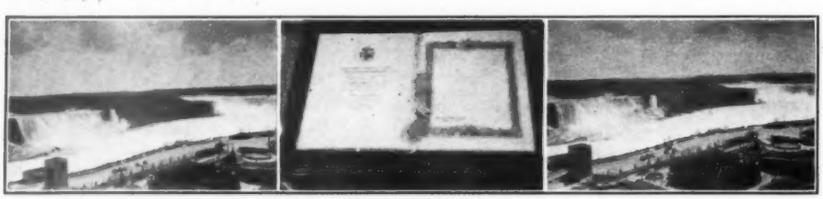
C. C. Folger, Kingston, Ont.

T. M. Kingston, Chatham, Ont.

A. L. McPhail, St. Catharines.

A. L. Peart, St. Thomas, Ont.

(All being managers of Public Utilities Commissions.)



View from the King and Queen's Suite in the General Brock—and the King and Queen's Book

Invited to Chairman Storrie's suite, this is the view from his windows. Incidentally, it was the suite occupied by King George and Queen Elizabeth during their stay in Niagara Falls. Treasured, is the King and Queen's book (center) in which their Majesties signed their names as the hotel's most distinguished guests.

Inspection Trip

One afternoon was devoted to a tour of inspection of the Niagara Falls Filter Plant and Pumping Station, where the army type of barbed-wire entanglement fencing could be observed surrounding the plant. To those from the States this was an interesting feature, as was the armed guards stationed at this plant supplying the important defense area that it does. Although we did bring back pictures of this fencing, such were not "declared," and their publication herein would hardly be "cricket," as the British put it, and, besides, we might go to jail for it.

Berry and the Canadian "Information Exchange"

Dr. A. E. Berry, Director, Sanitary Engineering Division of Ontario Department of Health, will continue his noteworthy job as Secretary-Treasurer of the Canadian Section, which through Dr. Berry's "Water Works Information Exchange" is performing an outstanding service to the 266 members. This "Information Exchange" is now entering its fifth volume. In his report to the Section, Dr. Berry explained a temporary deficit in stating that he had thought it wisdom to purchase ahead a supply of paper stock of the distinctive colors used in producing Information Exchange data sheets for filing or binding by members. President Howson took occasion to praise this valuable type of work being carried on by the Secretary of the Canadian Section.

Wartime Supply Problems of Canada

The feature of the program was perhaps the talk made by M. J. McHenry, Priority Officer, Ontario Hydro-Electric Power Commission, Toronto, on "Wartime Supply Problems."

He began by citing the following startling figures revealing how the United Nations stand in regard to control of the world's supply of basic

The "Water Works Club" Proved a Happy Innovation

At the Canadian Section meeting, entertaining in rooms was out. Instead, the Water Works Equipment Assn. of Canada held open-house during specified hours, after the close of technical sessions and again after the scheduled evening affairs. The "Club Room," just off the hotel lobby, proved the place for anybody to find everybody. The scheme was endorsed by all as a great idea and something to be repeated.

In these pictures, snapped at random, on the left is recognized McFaul (Hamilton), Redfern (Toronto) and Bunell (Director of Canadian Utilities Service Administration). At center, Secretary "Jim" Kinney and President George Morgan, of the Equipment Mfgrs.' Assn., argue as to which will make Chairman Storrie's high-ball.

The fourth picture has us guessing, but it can be seen that the ladies were invited also. Next (end picture) the convivial gentleman, telling a yarn and tamping his Dunhill, is "Ed." Buchanan of London, Ont.—an "ace" manager of Public Utilities and a "wheelhorse" in the Canadian Section. We agree that the "Water Works Club" was a worthy innovation.

The Show Is On—and a Good One

Don't blame the camera. The light wasn't much to boast about and the exposure of 1/10th second and lens wide open at F. 1.5 is a tough assignment when attempting to catch action. Anyway, it's fun to try it.

commodities in 1938 as contrasted with today. Here they are:

Commodity	—Per cent— 1938	1942
Rubber	100	8.9
Steel	76	56
Tin	91	26
Bauxite	78	34
Lead	91	78

As to metals alone, the relative scarcity is in this order: Vanadium, tin, tungsten, aluminum, nickel, steel, copper, zinc, brass, chromium, cadmium, and lead the least.

Officers

Trustee—A. L. McPhail, Supt. of Water, St. Catharines, Ont.

George Morgan, Victaulic Co., Ltd., Toronto (President, Water Works Equipment Assn. of Canada)

Trustee—T. M. S. Kingston, City Engineer, Chatham, Ont.

Mr. Henry pointed out the great need for Canada and the United States having dovetailing systems of priorities and allocation of materials. This because of great dependability of Canada on the U. S. for many supplies, electrical equipment in particular. Movements have been started to have the W. P. B. order P-46 apply in Canada also as a marked help to utilities. Although Canada's system has always been one of allocation almost completely, the U. S. priorities system really controls the Canadian supply for allocation. In Canada the maintenance and repair situation is suffering considerably because there is no priority rating which gives utilities any rights in replacement and repair materials. Since Canadian utilities have no priority numbers to place on orders, securing U. S. materials is an extremely difficult matter. Since, however, there was a good possibility of getting P-46 extended into Canada, there was light on the horizon. Mr. Henry lauded the W. P. B. on its methods of keeping industry informed constantly on priorities, changes and controls. In Canada, manufacturers lack knowledge of what can be done and there are too many places to go for allocations and licenses.

Mr. Henry stressed the fact that in Canada extensions by utilities is not permitted and appearances are out, service being the only matter that counts. He pleaded with water works men to keep spent materials moving and to keep the possibilities of substitutions for scarce materials foremost in mind—a challenge to engineers. His further plea was to gather together all possible metal scraps and put it back into circulation without waiting for what may be considered a worth moving lot. Every little helps more now than a lot later.

Following Mr. Henry, A. E. K. Bunell, Director of the Utilities Service Administration of Canadian Wartime Prices and Trade Board, presented a picture of price control which takes in utility rates as well as wages. Utility rates are based on prevailing rates during 90 days prior to Dec. 31, 1941. As to revisions upward, if conditions warrant, such is permitted. In cases of municipally operated utilities, as long as one is making a profit, the other may be losing, but no rate increase will be permitted until a net loss can be proven.

In Canada it has apparently been automatically required that wages to municipal employes be raised a prescribed per cent or a minimum per diem to meet increased living costs. Many case questions of a clarifying nature were put to Messrs. Henry and Bunell by members.

Because Canadian water utilities are experiencing considerable difficulty in securing materials for minor expansions, maintenance and repairs, a resolution was voted by the Section recommending to the Executive Committee that the Director General of Priorities at Ottawa introduce without delay suitable priority authorization to assure availability of such maintenance and repair supplies to water supply works.

Technical Sessions

(Chairman Wm. Storrie presiding)

"Influence of Plant Design and Construction Upon Filtration Problems, Illustrated by Special Reference to Buffalo, N. Y.," by Henry F. Wagner, Chief Chemist, Division of Water, Department of Public Works, Buffalo, N. Y.

Mr. Wagner discussed the disadvantages of experimenting in designing new filtration plants and pointed out that operating problems which

Programmers

H. C. Mills, Chief Filter Operator, Belleville, Ont.

Edw. V. Buchanan, Mgr. Public Utilities, London, Ont.

Norman G. MacDonald, Consulting Engr., Toronto

appear to be minor ones may have far-reaching effects. Raw water characteristics and proper treatment methods are now well established for most sections of this continent.

Proper preconditioning of water ahead of filtration is essential, and false economy at this point may be dangerous. Attempting to accomplish both mixing and flocculating operations in one step is an example of this. At Buffalo, while the low lift pumps provide excellent mixing of coagulant with the raw water, there were indications that the alum was not fully dissolved. Study showed the solution pots of the dry feed alum machines to be of insufficient capacity, giving only a few seconds actual detention time. Stainless steel dissolving tanks have been installed and a rotometer is used to control the water supply; result, better coagultaion and a saving of alum.

High wash water rates are possible only if the plant design provides ample freeboard above the sand level. A rise of 36 in. per minute is used at Buffalo, where overflow troughs

Present at the Past-Chairmen's Luncheon
(All being Past-Chairmen)
(Rear Row)—Ross Dobbin (Peterborough), Geo. H. Strickland (Windsor), Marcel Pequegnat (Kitchener), Chas. J. Des Baillets (Montreal), D. M. Hanna (Windsor).
(Front Row)—J. Clark Keith (Windsor), Wm. L. McFaul (Hamilton), E. V. Buchanan (London), Wm. E. MacDonald (Ottawa).
(Present at the meeting, but not at the luncheon, were Past-Chairmen W. C. Miller of St. Thomas and Norman J. Howard of Toronto.—Photograph by courtesy, "Water & Sewage" of Toronto.)

are 20 to 26 in. above the bed, and no sand is lost. It has been found that Anthrafilt not only enables longer filter runs, but that a saving of wash water is possible in those filters in which sand has been replaced by Anthrafilt. Better expansion of the bed is possible since a 0.7 mm. Anthrafilt weighs 55 lbs. per cu. ft. and a similar size of sand weighs 100 lbs. per cu. ft. At Buffalo substantial wash water rates are believed to be economical even though filters are equipped with Palmer filter agitators.

Adequate excess pumping capacity has proved its worth in several instances and a 24 hour reserve demand is not considered excessive. Clear water wells likewise should be of sufficient capacity to provide considerable storage during interruptions in filtration. These and many other practical experiences comprised a paper of exceptional interest.

In reply to questions, Mr. Wagner explained that the new alum mixing tanks have a detention time of 25 to 30 minutes and that the size was determined by laboratory study. Formerly considerable undissolved alum was found in the settled floc. Exact savings of coagulant cannot be determined until a longer operating period has elapsed. Filter beds in which all sand has been replaced with Anthrafilt are considered best, though existing sand filters may be "capped" with Anthrafilt to provide a top roughing filter layer.

Mr. L. R. Howson, Chicago (President, A.W.W.A.), commented on the extensive adoption of Palmer surface wash units in filtration plants of the Central Western States. In that locality it has been generally concluded that a wash water rise of no more than 24 in. per minute is required. Sand of more than usual effective size will be employed in the new Chicago filtration plant. Designed for 320 m.g.d., the filters will be operated at rates as high as 4 gal. per sq. ft. per minute. He agreed that only good operating experience could insure good engineering experience.

Mr. Wagner explained the high wash water rates at Buffalo as necessary, not to loosen accumulated sand coating but to raise and carry it to the overflow troughs. Bacterial removals are found to be the same on Anthrafilt or on sand beds.

"The Future of Water Chlorination," by Harry A. Faber, Research Chemist, The Chlorine Institute, Inc., New York.

Modern methods of water chlorination represent an evolution from simple to highly developed procedures. While the advantages of disinfecting polluted raw water with bleaching powder were recognized and while this form of treatment was coming into general use for a period of five years prior to 1912, it was not until that year that a real impetus was given to dependable chlorination. The first liquid chlorine made in America was produced at Niagara Falls, N. Y., in 1909 and the first device for feeding liquid chlorine for disinfection of water was placed in operation at the filtration plant of the same city in 1912.

Improvements in equipment followed rapidly, and now soundly designed devices for either gas feed or solution feed application of chlorine are available to provide doses ranging from a few ounces to several tons of chlorine per day. Effective chlorination depends upon a number of factors, of which only two can be readily controlled: the chlorine dose and the contact time. Definite progress was made when it was recognized that residual chlorine, rather than the original dose, provided the best assurance of bacterial kill.

Chlorine by-product or medicated tastes, which appeared in certain waters containing algae or industrial wastes, presented a problem. Then it was learned that the application of ammonia with chlorine would materially decrease taste and odor troubles while still enabling disinfection to be attained. Chlorine-ammonia treatment is now widely used, more especially to aid in carrying a persistent residual throughout the distribution system. By this means it is possible to prevent bacterial after-growths, biological decomposition in dead ends, and cer-

George Morgan
Victaulic Co. Ltd.
and
Jas. B. Kinney
W & T Co., Ltd.
(President and Secretary Water Wks. Equip. Assn.)

Donald McVicar
Operator
and
W. A. Allan
Supt. of Water
St. Thomas, Ont.

H. K. Jordan
President
and
John Britton
Representative
Canada Valve & Hyd. Co.
Brantford, Ont.

C. Edgar Brown, Manager
Public Utilities Comm.
Meaford, Ont.
and
Jack A. Leslie
Commissioner Pub. Utilities
Scarborough, Ont.

E. D. Case
Vice-Pres. & Genl. Mgr.
and
Cyrus R. Bird
Chicago District Mgr.
The Pitometer Co.
New York, N. Y.

James Harrison
Chief Plant Operator
Peterborough, Ont.
and
George Grabb, Supt.
Utilities Comm.
Chesley, Ont.

Geo. F. Shreve,
Manager Pub. Utilities
and
"Ted." Colvin
Supt. of Water
Oshawa, Ont.

Eskell Nordell
Chemical Engineer
The Permutit Co.
and
Stuart McWilliams
The Permutit Co.of Canada
Toronto

tain types of tuberculating slime bacteria.

Chlorine has found considerable use in manufacture of water coagulants, iron salts which are especially effective for treatment of waters high in iron and manganese. Another combination, that of chlorine with copper sulfate or of chlorine with ammonia and copper sulfate, has so far received only limited study. The application of metals or metal salts together with chlorine has been found by some investigators to increase the effectiveness of disinfection and to more readily destroy algae.

Only within the last three years have the full possibilities of chlorination alone been more clearly indicated. In ordinary chlorination, the residual chlorine is present as combined chlorine, held by nitrogenous compounds and less effective as an oxidizing agent. Studies show that when superchlorination is carried beyond the break point, the nitrogenous substances are broken down and chlorine can exist in a free and highly active form. The so-called "flash test" and other methods being developed provide a means of differentiating between active and inactive residual chlorine.

This more critical study and more critical evaluation of chlorination represents an outstanding development, since the most important reason for water chlorination is the destruction of bacteria. Not only is there new equipment which permits automtaic control of chlorine feed, but even the maintenance of a definite excess of chlorine, despite variations in the demand of the water, is now possible. Further development of oxidation-potential equipment will assure a more scientific control of chlorination.

With the better understanding of chlorine reactions, even further uses are possible in the future. There is already evidence that cysts of amebic dysentery and the virus of infantile paralysis may be destroyed by doses of chlorine well within practical limits. The modern use of so-called "wetting agents" in conjunction with chlorine has been found effective for surgical use and may even widen the application of chlorine in water purification.

"Modern Trends in Pumping Station Equipment," by Norman G. McDonald, of Gore and Storrie, Engineers, Toronto.

Mr. McDonald, in his excellent discussion of pumping equipment, in the very beginning pointed out that the municipal practice of accepting the lowest bid on pumping equipment frequently in the end proved the most costly practice possible. When considering power requirements day in and out, the most expensive pump could well pay for itself in short order due to the higher *maintained* efficiency and the first cost in reality should be completely forgotten in comparing bids. In other words, if bids could be analyzed on net cost per m.g. pumped over a period of years the most expensive pumps might prove the best investment by far. This matter of purchasing water works equipment on a first cost basis he loudly decried as a dear practice.

In discussing centrifugal pumps he reviewed the improvement in design resulting in markedly higher efficiencies of the centrifugal of today which involves the more costly design and construction for *low specific speeds* and propellers of the *radial flow* design for the higher heads. For the very low heads, the most efficient and overall economical pump for large capacity is the propeller type pump designed to secure *axial* flow at the center or eye of the impeller and *high specific speeds.* For intermediate conditions the most desirable pump is the relatively new design producing diagonal or mixed flow. He called attention to the newer designs permitting adjustments to propeller blade pitch to change capacity of the unit without loss of efficiency to more than about 5 per cent, an especially desirable feature for seasonal variations in demand. With the aid of power and head curves for four typical types of centrifugal pumps, Mr. McDonald showed that for fixed head conditions, high specific speed pumps would be economical, whereas for variable head conditions, low specific speed, variable speed drive or propellers with adjustable blades are essential for economical and safe operation.

The Delegation from Preston, Ont.

"Norm" Hobson
Commercial Mgr.
Chlorine & Alkali
Can. Indust., Ltd.
Montreal

W. R. Burr
Vice-Chrm.
Water and Light
Commission

Walter Denyes
Commissioner
of
Water and Light

F. O. Pelz
Chairman
Water & Light
Commission

I. C. Fink
Commissioner
of
Water

Ed Hansford
Chrm. Water Com.
St. Boniface,
Manitoba

G. A. H. Burr
Asst. Engineer
Ont. Dept. Health
Toronto

Concerning characteristics of centrifugal pumps, in choosing a unit to deliver direct into mains, the head-discharge curve should be a long flat one to insure a more constant pressure under variable draft conditions. For pumping against an open reservoir or tank on the system, the reverse is true. The steep head-discharge curve insures pump performance at full discharge capacity over the more even head to be pumped against. In such cases the nonoverloading type impeller can be employed.

To minimize end thrust, modern design involves use of double suction impellers with the water flow dividing equally, within the pump, to the two back-to-back faces of the one impeller. In this design for single and two stage pumps hardly ever is more than two stage units required.

In the important matter of wearing rings between the casing and impeller, Mr. McDonald pointed out that the ideal of extremely fine or close clearances must be superseded by practical consideration and sufficient clearance to avoid unbalanced wear or seizure. In other words, performance efficiency was to be considered on the basis of average over a substantial period of time and close clearance of wearing rings might produce a splendid efficiency picture for a brief time and then go downhill rapidly. The greater clearance between the rings and impellers might give a less impressive picture in the beginning, but a far better one for the long-pull service. In support of this statement, operating experiences were recounted. In a selection of wearing rings the so-called labyrinth type containing at least two or three bends should be specified. These rings permit the use of greater clearances without any important leakage (slippage) of water past the rings. For waters carrying fine sand or muck grit grooved rings, which may be continuously flushed with grit-free water, are available.

Cavitation, the common ailment of centrifugal pumps, indicated by the crackling noise like small gravel passing through the pump, is a condition chargeable to faulty design or operation under conditions for which the pump was not designed. The trouble may be caused by too high a specific speed or too great suction lift. In any case, the noise and pitting of pump parts is the result of the many partial vacuums set up and the later impact of water rushing into these voids or so-called cavities at tremendous speed.

Past Presidents of the Section

1—*Ross L. Dobbin, Manager, Utilities Comm. of Peterborough, Ont.*

2—*Warren C. Miller, City Engineer, St. Thomas, Ont.*

3—*Wm. L. McFaul, City Engineer, Hamilton, Ont.*

4—*Chas. J. Des Baillets, Chief Engr., Montreal Water Board*

5—*Geo. H. Strickland, Supt. Filtration, Windsor, Ont.*

Mr. McDonald pointed out the mistake often made of providing pumps for boosted fire pressures on the system but operation at normal heads lower than that producing highest efficiencies. The operating costs in such cases is wastefully high and the better economy would be to provide special standby units for fire service, or to provide booster pumps on a bypass in the station discharge line.

At this point Mr. McDonald discussed pump driving units at some length—motors, turbines, Diesel and gas engines. Control equipment for electric motor drive had recently been perfected at a rate exceeding electric motor improvements. For small municipal supplies the squirrel cage induction motor with full voltage starting and equipped with adjustable pitch shieves and V-belts constitutes a very economical, efficient and suitable drive. For the smaller installation of full voltage starting induction motors the simple magnetic starter with overload and under-voltage protection and operated by push button remains the most popular type of control. Where a pump is to be automatically controlled by a pressure or time switch or operated from a remote station, the magnetic starter is especially suitable, reliable and low in cost.

Diesel and gasoline engine drive was compared, the former being preferable for continuous or long period duty and the latter for standby duty. A chapter was devoted to the design of suction and discharge piping in pumping stations. The greatest common error made in the discharge piping of pumps is the use of an increasing bend almost immediately on the discharge nozzle. Such bends, if essential, should be of constant diameter and followed by a straight increaser. Better practice yet is the installation of an increaser directly on the nozzle so that the bend, when used, will have a low velocity and low head loss.

Concerning check valves, wear of these units at the hinge has been the most noticeable defect, and these valves should be provided with renewable bushings in the valve body to reduce wear and permit of repairs being quickly made. An improved check consists of a streamlined tilting disc which is held wide open in non-fluttering position during pumping. Thus hinge wear is minimized greatly and since the hinges are well constructed and lubricated, its maintenance cost is low. This check has no apparent particular superiority over others in the matter of valve slam but it creates considerably less head loss. The cone type valve with its dual function of check and shut-off is the preferred unit for pump discharge lines in spite of its greater cost.

In an analysis of metering devices the venturi is first choice from the standpoint of head sacrifice. In this direction tubes with larger throats, producing lower head differentials, are being chosen since modern recording equipment is capable of operating accurately under lower differentials than in earlier years. Mr. McDonald warned of the likely inaccuracy of venturi meters unless there be a straight line flow to the meter representing 12 diameters, at least, of the pipe. On meters with low differential and, even greater length should be used.

In closing, Mr. McDonald returned to the theme of "getting what you pay for" when purchasing motor-pump units and cited cases to prove that quality pumping equipment soon pays for itself in power cost reduction.

Guided Discussions

Under the head of "Guided Discussions" the first topic was in reality the presentation of a survey made by Ross L. Dobbin of Peterboro indicating an almost universal increase

in the per capita figures for water consumption during the past year. The conspicuous exception proved to be the St. Thomas case, in which metering had been effective in reducing an 84.5 gal./capita/day consumption to 69, the latter figure being lower still if computed without increases in industrial consumption being included.

Topic No. 2—Maintenance of Filter Beds and Control Equipment

(Leader—O. H. Scott, Belleville, Ont.)

Q.—How frequently should filter walls and wash troughs be cleaned?

In answer, Geo. H. Strickland of Windsor, who stated that the upper walls should receive frequent attention and the lower walls once yearly with hot copper-sulphate solution. Troughs are cleaned once yearly and repainted every three years. Hydraulic valves are overhauled every five years and painting of pipes, etc., is done every four years.

Q.—Should filter beds be cleaned other than by back-washing; how frequently? Can mud balls be avoided?

Norman J. Howard felt that mud ball formation signified one or more of the following: Water imperfectly coagulated; sand quality poor in regards to having too much fines; faulty washing. Relative to the high importance of proper sand quality and size of grains, Mr. Howard commented on the excellence of results obtained with crushed anthracite ("Anthrafilt") of an 0.8 mm. size. The bacterial efficiency had been astoundingly good and the "Anthrafilt" more readily washed clean. He was of the opinion that "Anthrafilt" deserved more attention than had been given this media. Mr. Howard had not found a combination of sand and "Anthrafilt" bed satisfactory because of mixing taking place during washing.

To remove mud balls at Welland, Ont., J. C. Street places top 2 inches of sand on a fine screen resting on the wash troughs, and breaks them up with a hose stream. A rake with wire mitting attached is used at each washing to pull out mud balls.

At Belleville, Mr. Mills recirculates the top 5 inches of the beds through ejectors, it requiring 4 to 15 recirculations to produce clean sand. The clean sand sinks and more mud balls come to the surface. After many repetitions of the cleaning, the bed could now be considered clean. High Test Hypochlorite (HTH) was also employed at the rate of 4 lbs. per 1 m.g.d. filter with further good effects. Since the cleaning, the freeboard has increased from 27½ inches to 36¼ inches.

Mr. Scott then revealed that "Anthrafilt" was being tried alone and in various combinations with sand.

Q.—How often should filter underdrains be uncovered and examined?

G. H. Strickland said that he didn't know. The Windsor bottoms haven't been uncovered in 20 years. Returning to mud balls, Mr. Strickland believes that the quality of pre-treatment of the water is all important. In filter washing they employ a 4 minute wash at 50 per cent of the regular wash, followed by full rate, which is only an 18 in. rise giving maximum of 30 per cent bed expansion of 0.5 mm. sand.

H. G. Turner, State College, Pa., representing the Anthracite Institute, suggested that *clean* coarse grained filter beds should be good for twice the customary rate of 2 gal./sq. ft./min. He warned against trying "Anthrafilt" on top of sand unless more form of bed agitation is available to preclude accumulation of mud layers between the coal and the heavier sand beneath. In this connection he described the thoroughness of the Palmer Filter Agitator for deep bed washing as well as surface wash.

Intake Ice Troubles

This topic was introduced by Geo. F. Shreve, Manager of Utilities, Oshwa, Ont., who recited the calamity which befell Oshwa when snow and slush ice in the lake extended down 27 ft. to seal the intake 2,600 ft. offshore, reducing flow to a mere trickle. Without means for putting back pressure on the line, nothing else helped until Nature removed the snow field or caused it to float.

Geo. H. Strickland, in answer to a question, stated that the Windsor intakes are equipped for back washing ice from the intake with high pressure water. An important consideration is to watch for first indications of onset of ice over the intake. In 15 years only on two occasions had back flushing been necessary. The scheme involves the closing of the 42 in. valves and turning in the pressure water, only about 20 minutes being required.

Diversion of Water Funds

The last topic for discussion was a "Member's Choice," which proved to be a warm one. It developed into a recital by managers and commissioners of their problems in the matter of diversion of surplus water funds to other city uses.

Mr. Hatcher of Galt, Ont., told how every three months he had been required to hand over all surplus to the Municipal Government.

Mr. McCloud of Hanford, Ont., related how the City Administration had blocked the Commission from installing much needed meters for conservation of water needed by a new war industry. A fight ensued but the court ordered the Commission to turn over $16,000 surplus to the city and keep only $285 for water utility uses.

After this recital a Commissioner was loud in his complaint that Commissioners as a group had not been given sufficient voice in the activities of the Section on matters pertaining to policy and there should be some assurance given by the utility manager group that this problem of ways and means to stop diversion of water funds would receive the attention deserved. He wanted a resolution passed on it at *this* meeting.

At this point Chairman Storrie had a few words to say. He pointed out that the manager was the employee of the Commissioners, who were the proper authorities to set up and enforce policies. The present Utilities Commission Act of Canada is sufficient if lived up to by all parties. No municipality has any rights to direct surplus water funds so long as any of the debentures are outstanding. Neither have the Commissioners any right to borrow money from banks, but they do in many instances. Mr. Storrie suggested that a body should be set up to adjust differences which arise between Utility Commissions and the Municipal Administrations.

E. V. Buchanan, Manager of Utilities, London, Ont., recently faced with the same problem, averted it by telling the City Administration that before any funds were to be taken from the water surplus it would be the Commission's duty under law to make a rebate to customers on past payments that were rightfully theirs. Otherwise the surplus is being accumulated for the purpose of installing needed water softening in London, but only after the war is first won. That proved one answer that was apparently sufficient for the time at least, said Mr. Buchanan.

After this the resolution demanded was drawn, discussed and redrawn many times. In its final form it was a *request* to the Executive Committee to go further in their efforts to have the evil of funds diversions stopped.

INVISIBLE LIGHT USED TO FIGHT SABOTAGE

By R. E. APPEL
Worner Products Corp.,
CHICAGO

BECAUSE we were a nation devoted to peace it has taken a long time to prepare our minds for the full realization of what "total war" means. Some opinion analysts doubt that we have reached that full realization even now. It is obvious that we have not fully awakened to our dangers from within at the hands of our hidden enemies, the saboteurs. Industries and municipalities are just beginning to see the imperative need of vigilance against internal enemies.

The larger industrial plants now are adding to their protection by supplementing guard duty with anti-sabotage photoelectric equipment. Smaller concerns without armed guards are using such equipment to do the entire job of protecting against the saboteur.

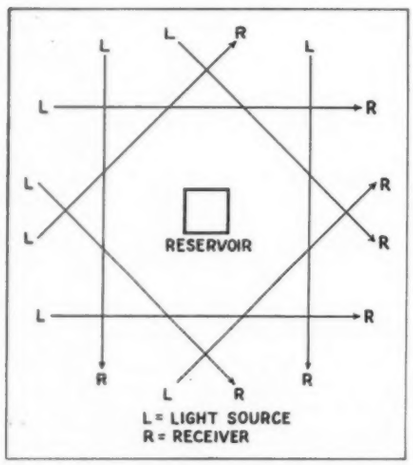


Fig. 1—An Installation Pattern for Guarding a Tank, Gate House, Well, Small Reservoir, Etc.
Light Source Units (L) Throwing Infra-Red Beams to the Receiver Units (R) opposite, to form the "Invisible Fence."

This method is used by many electric and gas utility companies and to some extent by water works, but a full awakening to the dangers from internal enemies does not appear to have yet come to the water works field. Our enemies are making their own rules of warfare as they go along and nothing may be expected to deter them from using any means to further their objectives.

The Principles of Photoelectric Guarding

Those who already know the operating principles of photoelectric detection will pardon the insertion here of a brief explanation for the benefit of those unfamiliar with this form of electronics.

Essentials consist of a light-source and a receiver. The light source is an electrical unit which projects a concentrated beam of light through a light filter which produces invisible (infra-red) light. In the other unit, called a receiver, is a photocell which responds to the light beam projected onto it. Under the action of the light from the beam reaching the receiver an electric current flows through the circuit of which the energized photocell is a part. The instant that the beam is interrupted, current stops flowing in the photocell circuit. Through a system of amplifiers and relays in the receiver, this unit becomes a switch for operating any alarm or signal system to which it is connected. Any interruption of the infra-red light beam does the switching and operates the alarm and signal system. Such an interruption would be created by a man passing through the invisible beam (light fence) between the two units.

On these principles is built the photoelectric anti-sabotage equipment, but much elaboration and scientific development, based on the principles, are evident in the best of such anti-sabotage sets.

How the Light Sources and Receivers Are Installed

Naturally the reader will raise the question of how an installation for the protection of a water works is made. Details of any particular installation cannot be published for obvious reasons. However, certain generalities may be stated here.

Figure 1 shows the general principles used in laying out an "invisible fence" to guard small open reservoirs, tanks, gate-houses, wells, etc.

Figure 2 shows in greater detail a "corner" of the invisible fence.

Anti-sabotage units for outdoor installations must be firmly supported in the proper position. The writer's company accomplishes this by providing the instrument cases with a screw flange in the base. These flanges are threaded for 1½ inch pipe, which is used for stancheons to support them, as shown in the installation pictured. Cement blocks, poured into the earth, well below the frost line, are used to support the 1½ inch pipe used for stancheons.

Interiors of buildings are also guarded by anti-sabotage units. These are similar to the outdoor units except that they are usually made to operate over a shorter distance and are not in weatherproof cases. They are supported by wall brackets instead of stancheons. In protecting interiors having small areas, the number of units required may, in some cases, be diminished

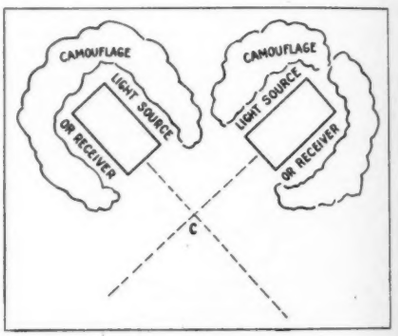
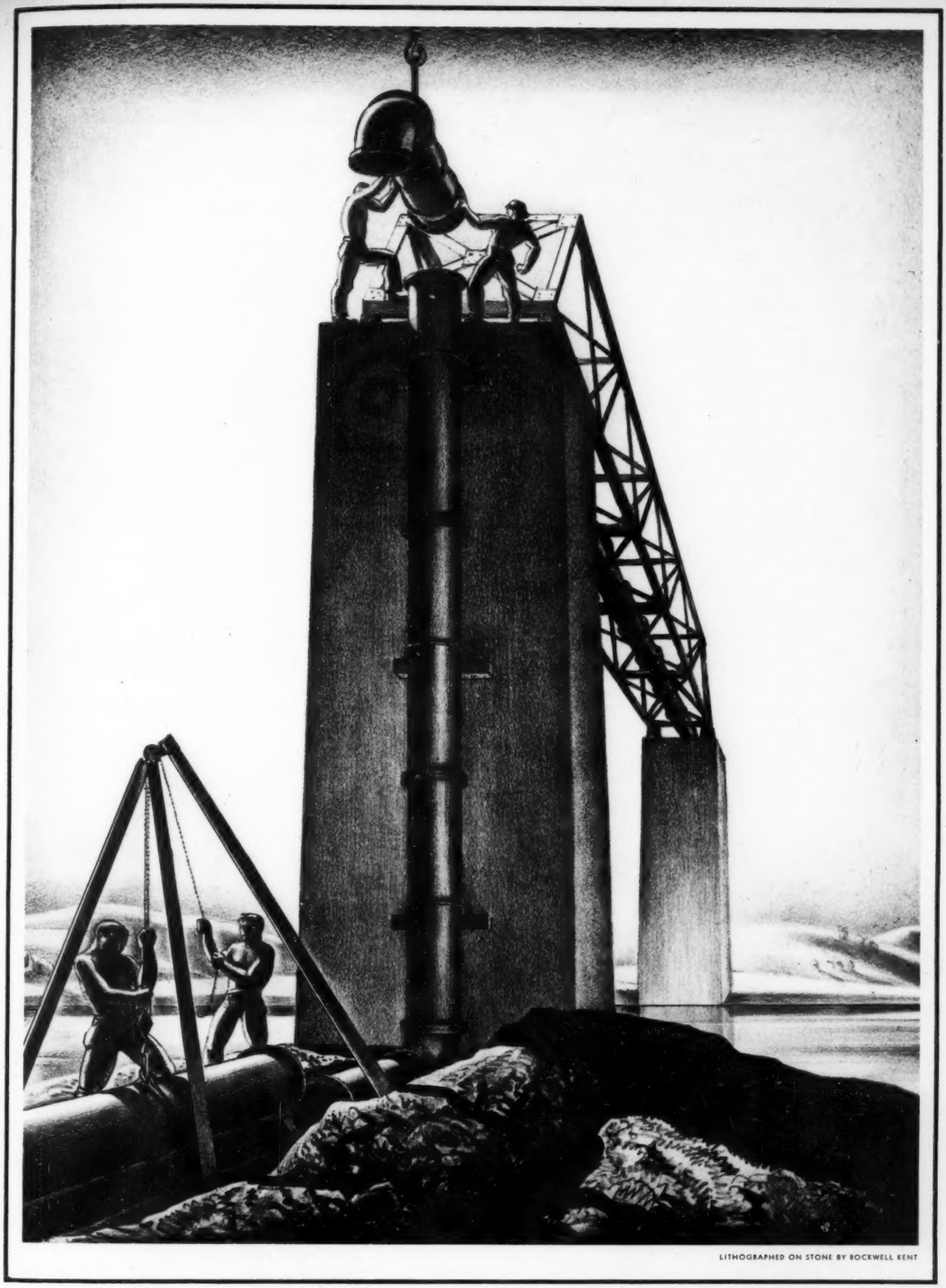


Fig. 2—A Fence Corner.
Is Produced at (C) Where the Beams Passing Between Light Source and Receiver Units Cross.

by using special focusing wall mirrors to reflect the beam from the light source unit. In that way the beam from a single source may be made to criss-cross the room a number of times. Interruption of a reflected beam has the same effect as breaking a direct beam.

Anti-sabotage units may be connected to operate any type of alarm or signal device. Where a number of units are installed, they are usually made to operate signal lights at a central point when trespass occurs. Such a system not only gives warning but also locates the trespasser.



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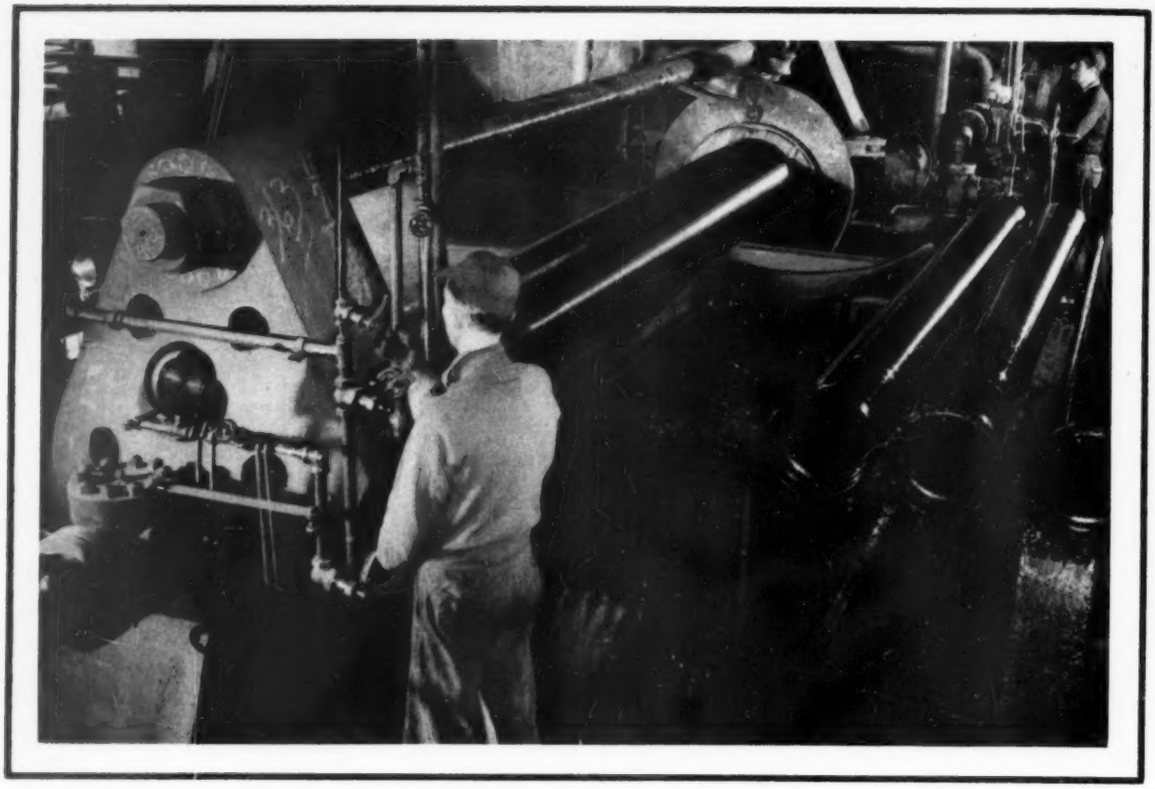

* The "Hydrostatic Proof Test," illustrated above, is an acceptance test for cast iron pipe. Every full length of pipe—whether for water, gas, sewer or industrial service—is subjected to this test before shipment. It is one of the routine tests made by this Company to insure that the quality of its pipe meets or exceeds the requirements of accepted standard specifications for cast iron pipe.

* One of a series of controls in operation at each of our plants, beginning with inspection and analysis of raw materials and ending with tests of the finished product, all subject to the central control of our headquarters staff at Burlington.

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OPERATION OF DISTRIBUTION SYSTEMS UNDER BOMBING CONDITIONS

A Summary and Conclusions Based Principally on English Experience

By RICHARD BENNETT
Hydraulic Engineer
MUNICIPAL WATER WORKS
PHOENIX, ARIZONA

NOW that the United States is trading bombs and rifle fire with a nation whose capacity for peace is nil—a nation having master minds capable only of treachery and deceit—it is proper to consider the possibility of sabotage and actual warfare striking at our plants, and to plan for these contingencies in the light of experience gained by others.

During times of war, the maintenance of an adequate water supply becomes an essential line of defense for all municipalities—first to sustain life, and secondly to save property from bomb fires. As few cities are provided with secondary fire protection systems, it is necessary that water service be maintained in a condition fit for domestic needs, regardless of the demand made upon the system. Breakage and destruction of water mains and sewers from bombs may happen here, and to prevent pollution and maintain constant service will call for forces and materials so well organized that they will function according to planned procedure. Those in responsible charge of water works must first determine the vulnerable points in the system and secondly, plan a method of procedure to protect them.

Sterilization

Probably no method of safeguarding against pollution is better than chlorination, whether the contamination is deliberate or accidental. If bombs come, a high chlorine residual should be maintained throughout the distribution system; it is not safe to depend merely upon heavily chlorinating the supply. The taste and odor of chlorine become of little importance when health is at stake. The British public has learned that a chlorinous taste spells safety, and complaints on this score are now few. Breaks, cross-connections, back-siphonage, and the work of saboteurs must all be considered. The use of chloramines probably will be necessary—a practice which will please the public by giving better taste.

Chlorine Equipment And Supplies

Reserve chlorine equipment should be provided, so that quality may be maintained in the system, even though the regular equipment may be rendered useless. This emergency equipment should be procured immediately, as the demands will not be fulfilled, once the real need develops. As chlorine is no longer permitted for many swimming pools, some equipment will be available from this source.

The Author*

Hypochlorinators can be secured with sufficient capacity to meet the needs of all but the larger cities. This equipment may be used with both dilute and concentrated solutions. Sludge difficulties will not arise if an attendant keeps the sludge stirred up. The best practice is to make up the solution, allow it to settle, and then siphon off the clear supernatant liquid into another tank for use.

The hypochlorinator may be used for both main sterilization and emergency use. It is easily portable, usually being carried by two men. When the hypochlorinator is actuated by a water meter in a by-pass hose line, the quantity applied may be closely regulated.

Portable Equipment

Each water works should have at least one portable chlorinator with several cylinders of chlorine, suitably mounted, to meet emergency conditions anywhere in the system. Some of the units now available are complete in every respect, requiring at most two taps in the main to inject either gas or solution under pressure. Some of the hypochlorinators are equipped with a small gas engine drive, which makes them suitable to meet almost any condition of use.

Emergency chlorinating equipment should have sufficient capacity to apply treatment of not less than 1 p.p.m. to the maximum flow treated. Under some circumstances sufficient pressure may not be available to properly operate the chlorinator injector. Therefore provision should be made to continue the treatment with a low water pressure, or by auxilliary pressure supplied by means of a portable engine and pump.

An ample reserve of chlorine should be provided to meet any unusual situations. Either liquid or powdered form is suitable; and in an emergency the chlorine bleach used by launderies can become an adequate source of supply. All chlorinating equipment should be frequently tested to determine that it is in operating condition. Gaskets and packing cannot last indefinitely, nor should they be expected to do so. Leaking chlorine will corrode and possibly ruin the equipment.

Emergency Chlorination

Emergency disinfection of bombed water mains is vital, as it is invariably found that the adjacent sewer has been blow to bits, permitting raw sewage to fill the crater containing the water main. Disinfection must be swift and sure; and a good water works man will go the limit to prevent the use of untreated water by either civilians or military.

English Experience And Practice

Water works face no greater danger of pollution from any cause than from bombs. Debris, such as dirt, and especially broken pieces of the main, have been found as far as 600-feet inside the pipe after a bomb blast. In England, greater attention to emergency sterilization is given to mains 12-inch and larger in size. For these mains liquid chlorine is generally used. They feel it is undesirable to place too many cocks in the small mains, therefore depend largely upon the effects of high test hypochlorite for sterilization.

It is not enough merely to chlorinate when pollution is suspected. Pollution is not easily detected. A visual examination is not to be depended upon. One cannot tell how far pollution may have been distributed inside a blasted main. A bomb crater may not show any broken sewers, yet carry strong odors of sewage. In areas subject to bombing, a chlorine residual of about one p.p.m. should be maintained as emergency protection.

High residuals must be carried where there has been possible contamination. Residuals of one to ten parts per million are quite common, and in some cases may necessarily be higher. Boiling will drive off the chlorinous odor.

The foreman of the repair crew should be provided with a table show-

*Secretary, Arizona Sewage and Water Works Association.

ing the amount of chlorine to add, depending upon size and length of the main affected. The chlorine must be applied at a point where it will be carried properly into the polluted sections. Often-times existing corporation cocks will serve: if not, the main should be tapped. The heavily chlorinated water should be held in the main for at least 30 minutes (one hour is better), with a distinct odor of chlorine persisting. If the chlorine odor fades out in this time. the dosage should be increased. In England, to kill the chlorinous odors and tastes after the water is drawn out and fresh water introduced, they use hyposulfite of soda in weight equal to the chlorine added.

After the repaired main is chlorinated, it should be thoroughly flushed, permitting the water to waste through a blow-off valve, air vent or nearby hydrant. The point of discharge must be at the opposite end from that at which the main is filled and chlorinated, and the flushing must continue until the entire isolated section is cleansed. Some flush the main in both directions for best results. After the main is flushed, each consumer is asked to run his taps for one-half hour, and advised that drinking water for the next six days should be boiled. When the bombs come the public soon gets "water conscious" and does not get perturbed when asked to boil all drinking water.

New Mains

All new water mains should be heavily chlorinated, and samples taken before they are put into use. The chlorinated water, 40 to 100 p.p.m. residual, is kept in the main from a minimum of about four hours to overnight. Complete records should be kept of this sterilization work together with the results of samples; and filed for future reference.

In laying new mains, each length of pipe is thoroughly swabbed inside with a strong chlorine solution by means of a mop mounted on a long handle. Both ends of the pipe are now sealed with expanding stoppers, which are removed only when the ends are joined in the trench. Specials and valves should be similiarly treated and handled. Service crews should wipe the tapping drills and materials with chlorine solution, to prevent pollution from this source.

Meters should be dipped in chlorine solution before being installed, and the ends capped to prevent debris from entering the meter. Hydrants should also be sterilized in this manner.

Pollution

English cities have devoted much attention to preventing pollution of potable water supplies. So far in this war, it is believed, that no water borne epidemics have occurred. Many tests have been made on the pollution of reservoirs, with negative results. The mere presence of bacteria in a body of water does not mean that those who drink this water will contract the illness: such factors as the quantity of bacteria absorbed and the immunity of the person determine the result.

Widespread pollution due to sabotage is not probable because the desired results would not be assured; and the saboteur is therefore more likely to direct his talent in other directions. However, attention is again being given to the concentration of dried typhoid germs to about 1/20th of their original weight. Although I have been unable to reach positive conclusions in this subject, I feel that we must regard it as a danger.

Fire Protection

One of the major problems of modern warfare is the fighting of fires due to bombs. If a large excess draft is placed on the distribution system, it becomes increasingly difficult to maintain the quality of the water in the system, but even considerations of health must give way to the needs of fire fighting. However, this must not be construed as advocating polluted cross-connection supplies.

If the fire insurance investigators have recommended certain reinforcements or improvements to your system, these should not be deferred, as the chances are that the system will be too weak to meet all the exigencies of war. Only the closest co-operation between water works and fire department will fully meet the situations which may arise. Each must be fully informed of the problems of the other.

All water consumers should be warned to limit domestic use and conserve the water and pressure available for the use of the fire department in case of bomb fires. This necessary notification must be arranged before trouble occurs. All leakage from the system should be discovered and eliminated, and all unnecessary uses of water curtailed.

As to the probable amount of water which will be required for fires caused by bombs, not much can be said, inasmuch as little or not data on this subject has come from England. However, the draft will probably require the entire facilities of any water works. If the mains are broken, then the problem is further complicated. As the breakage of large mains must be anticipated, supplementary supplies stored in large steel tanks, burned-out basements, and other improvised reservoirs are provided.

England has found an unexpected difficulty in the collapse of buildings over hydrants, valves, etc. The location of all such points of danger in the system should be noted, and possible changes made to eliminate as many of them as possible.

Procedure Following Bombing

No two situations are ever the same, but there are certain fundamental methods of procedure to minimize bomb damage. The following routine has been found applicable in many instances:

1. Valve off the affected area, closing those valves as close as possible to the breaks.
2. Provide by-pass supply if possible to maintain the supply in the area.
3. Repair the damaged water mains.
4. Take all necessary steps to deal with contamination.
5. Provide water from auxiliary supplies if necessary.

The more important or larger mains must obviously be handled first. Sometimes it is possible to resume service immediately by connecting the ends of the damaged main with special flexible rubber tubing across the break. This gives the repair crew a chance to effect a proper repair and maintain water service in the area at the same time. Whatever method of repair is used, the size of the main will be a determining factor.

After the repair crew arrives at the site of the damage, and while the crew are valving off the area, the foreman in charge should gather all information regarding the extent of damage, so that all necessary equipment, and no more, may be quickly brought to the scene. Damage to water pipes is a matter of chance; the damage is usually not confined to a single point, but the morning following air raids generally discloses that widespread repairs are required. To meet such emergencies, one should never forget that putting two water mains in the same street is very bad practice: trouble is doubled by that practice.

Maintenance of Water Service

Few people realize the tremendous penetration of modern bombs, and damage which may result, due largely to earth shock. Water mains may be damaged as much as fifty feet from the crater, the distance of effect depending upon many factors, such as weight of bomb, depth of explosion, material penetrated, length of delay fuse, etc. The average diameter of crators is about 20 feet. If the penetration is considerable, the explosion acts as a tamped charge and causes damage over a large area. The shattering waves, propagated through the earth, produce a displacement of materials in a radial direction. The vibrations cause joint leaks which often give no visible indication of their location, further complicating the problem of repairs.

For temporary supplies of drinking water, it may be possible to establish by-pass lines, by means of hose connections laid along the street gutters. Usually such connections are made to nearby fire hydrants. In case a large district has been deprived of its domestic water supply it may be necessary to provide sterilized water in tank wagons. No satisfactory method of providing industrial supply has been found until complete service is resumed.

Auxiliary Supplies

The cities of England found to their sorrow that they had not given sufficient consideration before the war to the provision of emergency water supplies. In this country a survey should

be made in each community to inventory all possible sources of supply. Irrigation, industrial, private, and other sources should be tabulated, and their capacity and dependability determined. Laundry plants and soft drink concerns generally have large, pure supplies which may be used without further treatment. These plants should be used in an emergency. The fire department is vitally interested in these sources of supply, and their active cooperation should be sought. Power facilities should be a matter of record.

London has provided many hundreds of tank trucks, with capacities from 500 to 2,000 gallons each; and in emergencies they have used gasoline and milk tank trucks to deliver drinking water. Sufficient equipment of this nature must be provided to supply the minimum quantity of water for persons in areas where the supply has been discontinued. The operators of this equipment should be trained for this special type of service, and the community must be educated and prepared to cooperate with such service when it becomes necessary.

Many English cities have portable pumps which may be moved into the pumping plants if bombs damage the main pumping equipment. Such duplication of equipment has much merit.

Large Supply Mains

Probably the most serious disruption of service would be the breaking of the main supply lines—a remote possibility, yet one that can happen. To disrupt the line by sabotage, probably would require so much preparation that detection would be unavoidable before damage could be effective. Direct hits by bombs are not likely, as the smallness of the object affords considerable protection.

However, these long supply mains afford a number of assailable points which should be given protection of some sort. River crossings, especially if carried on bridges, are readily open to damage in various ways. Gate valves, air release valves, air intake valves, blow-off valves, pressure reducing valves, manholes, and all such features should be covered with earth wherever possible, so that identification or location of the structure is difficult. The engineering division can easily provide relations records of such buried structures. Such points provide access to the water for infection or poisoning. If they can't be buried, they should be placed in substantial vaults with strong locks. Frequent patrols of the lines should be made, and all such structures inspected to make sure that they are in good working condition and have not been tampered with.

In reconstructing structures of this nature, the English have found that contractors' forces and equipment effected the repairs more speedily and effectively than the regular water works personnel. A survey should be made to determine who would be available for emergencies of this nature.

Valves

It is the experience of water works men that gate valves seldom, if ever, give trouble except when being operated. The stem seems to be the weak line in valve design; but the fact must not be overlooked that careless and inexperienced valve operators can quickly ruin any valve.

It is very important that regular valve inspections be made and the results of the survey filed for permanent record. In cold climates these inspections should be made at least twice yearly—spring and fall. All faulty valves must be repaired as quickly as possible—nothing less than first class operating condition should be tolerated at any time, as under war stress conditions these maintenance costs pay large dividends.

Valve operators must be thoroughly familiar with their districts, and know the characteristics of each and every valve. Complete and accurate records are of untold value. Operators must see that all valves that are supposed to be open, are open, and those which are supposed to be closed, are closed. Each operator should be provided with maps showing the location of every valve, with sufficient identifying points, so that if one measuring point is destroyed, another point may be substituted. Maps of this nature must be guarded from enemy agents.

In the larger systems, power-operated valves with remote control should be placed in the strategic locations; so that the more important areas may be valved off from a central control. There are many advantages from such use of automatic equipment. For maintenance purposes, the waterworks must have a complete stock, not only of repair parts, but of complete valves of every size and description, for it can be expected, that complete valves must be replaced at times.

Damaged water mains must be valved off as quickly as possible, not only to conserve water, but to prevent greater damage to surrounding structures, and further chances for pollution. Only trained personnel can be successfully used for this purpose, and of necessity they must frequently work under grave danger, even while the bomb raid continues. The valve operators are the first group to function after the bomb raid—the repair men are the second group.

The present war has clearly demonstrated that the distribution system should be well provided with valves, so that sections of not more than 500 feet of main in the mercantile and industrial areas and not more than 800 feet of main in the residence areas may be readily cut off from the rest of the system. This will require a valve on each main entering a street intersection, or three to four valves for each intersection. A complete survey will disclose the necessity for additional valves. Bear in mind at all times, that the cost of valves is much less than the loss of a single building. Some street interesections may be quite vulnerable to bomb attack; and therefore it may be necessary that locations of certain valves should be altered. In other cases the location should be changed so that if buildings fall a minimum of excavation or shifting of debris will be necessary.

Delayed action bombs have greatly increased the hazards of the valve operators. If an unexploded bomb exists, valve off this area just as if the bomb had exploded, until the bomb disposal squad can eliminate the hazard. Valves offer excellent opportunities for malicious acts. They can be closed during conflagrations; the valve box may be tightly packed with debris; or other mischief done. At times it is necessary to conceal the box covers, in which cases reference measurements must be made and recorded. During large fires it may be necessary to place guards over each important valve.

All curb stops of every size to unoccupied buildings should be kept rigidly closed; otherwise they will permit waste of water. Such curb stops also offer opportunities for introduction of poisons and infectious liquids into the system by the use of pumps.

Emergency Supplies and Equipment

Cities in England experienced much difficulty in securing necessary emergency supplies in the early part of the war, and it was not until actual bomb damage came that those in control relinquished such supplies. In this country, each water works should be provided with such special materials as may be necessary to effect quick temporary repairs; also stock for regular water main repairs must be greatly increased. The present emergency will naturally restrict the ready replenishment of existing stocks and increase the difficulty of securing stand-by materials.

In normal times it is considered good management to have a reserve stock of about 150 per cent of the amount of supplies which will be required before replenishment can be accomplished; but during war time it is better to carry not less than 250 per cent of the stock which will be consumed while additional supplies are being secured. Preparedness planning of this nature is an important part of the defense of each water works. All possible emergencies must be charted and action planned to meet any condition which may arise.

Supplies

Those in charge of each local water works are best fitted to determine just what emergency supplies should be provided. Requirements vary with local conditions, but it is plain that most water works should carry an ample stock of repair parts for pumps, motors, chlorinating equipment, and other mechanical units, as well as repair parts for valves and hydrants, sleeves, couplings, pipe plugs, fire hose, tees, crosses, reducers, wyes, chlorine, and various pipe materials. Above all, do not keep all supplies in one storage

location, for this can be disastrous when bombs fall.

In making quick emergency repairs there is little time to run lead joints; therefore joints must be made of the flexible, screwed, or detachable types. Many fittings of this nature are available. Plugs, of various types, are essential to close the ends of broken mains. The tapered wooden plug, held in place with steel band and rods is always to be considered. Cast iron plugs, of patented types are all excellent. Plugs permit continued service in many districts which would otherwise be without water service. Sleeves also permit quick repairs; and nothing has yet been found which is so essential for repair work. If the system contains no wyes, this item should not be stocked, but on those systems where wyes have been installed, a plentiful supply should be kept. Wyes are more apt to break than other fittings, the design being fundamentally weak against rupture.

It is not necessary to secure close fitting repairs for emergency work. Temporary pipe lines, joined with sleeves, may be laid above ground. Most of the pipe supply should be selected with reference to the facility with which it may be laid during an emergency. Under some conditions, steel pipe with welded joints may be suitable. Steel pipes with flanged connections are easily laid, but this type of joint is difficult to secure at the present time. In England, much use has been made of cement-asbestos pipe for emergency repairs. It is light, easily transported, and quickly and easily assembled and connected.

For bridging craters, telescopic pipe sections are extensively used. A pipe section with a gland connector which is large enough to fit over fractured mains is applicable many times. Often-times use is made of several lines of fire hose, in which case special hydrant connectors must be provided. Four lines of 2½-inch hose are equal to a 4-inch water main.

Stand-by Power and Equipment

If only one source of power is depended upon, the water supply may fail in emergency; and many water works have accordingly installed stand-by Diesel or electric power. Such auxiliary supplies must be adequate, that is, sufficient to meet all power needs.

Equipment to meet emergency needs should include trucks, excavating machines, compressors, cranes, trench pumps, etc., all of which are necessary to make repairs quickly. Portable lighting and pumping units, independently powered, are necessary for each emergency repair crew. Records of equipment replacement should be reviewed for the past ten years, and from these data a definite policy formulated. The need for heavy equipment increases during war times, while the ability to secure it is lessened, but government authority for delivery can be secured where the need really exists.

Equipment and Supply Pools

England has provided legislation enabling the water works administrations to form themselves into various pools to assist each other in maintaining service, and to purchase, as a pool, all necessary equipment and supplies to meet their needs. The pools serve all member water works and the cost is borne proportionately.

These materials and items of special equipment are deposited at convenient locations. This saves much expense to all; and the formation of these mutual assistance pools has been amply justified. In many instances these pools have provided immediately personnel and materials which otherwise would not have been available. Such assistance makes available the resources of the unaffected areas to meet any local needs.

Tests for the satisfactory operation of emergency equipment, should be frequent. Keep reports of such tests. Every possibility of adverse operation should be anticipated, and the capacity of each unit definitely known and properly allowed for in emergency plans. The frequency of such tests should be increased above normal schedules.

Emergency Crews

Quick and effective repairs to damaged distribution systems require that special crews be provided and trained. The men comprising these crews must be versatile; not only knowing how to make repairs, but also trained in first aid to meet various emergencies. These crews should be an expansion of the present water works crews, and the work done under the direction of the water works men in charge. It is not logical that just anyone be designated to carry out such important and skilled work.

The emergency crew members must be energetic and ambitious—men eager to do their full share of the task confronting them—for only when such a spirit prevails can the work be accomplished quickly and efficiently. Means must be provided for the quick discovery and reporting of breaks and damage.

War emergency work requires 24-hour schedules; and the crews must be strategically located over the area, to be on the job quickly when needed. They must be in communication with patrol headquarters to receive all information quickly. Their shifts must be such that their service areas are not left unprotected at any time.

Under ordinary circumstances it may be said that the time required to repair a water main will be about one hour for each inch of diameter of the main affected; but if deep crators, large piles of debris, masonry structures, etc., interfere, the required time will necessarily be increased—even to several days in some instances.

Valve operators are the first men on the job when bombs have damaged the distribution system. These men are on first call, other members of the crew reporting only when a raid is sounded. Some members of the valve crew should be ready for duty at any moment; and they must carry on with their work, except when it is absolutely necessary to take cover from bombs.

After damage is reported these men go out and close off or isolate the district. Their headquarters is generally the air raid warden's post, where they are in communication with the water works officer at the central control post. They must report whenever the air raid warning is received or it is evident that an attack has been made. They are provided with protective clothing, full plans of the water valves, first-aid outfit, message forms, valve keys, hammer, etc. Duplicate sets of tools and equipment must be kept for them. They must be careful of unexploded bombs, and leave such areas to those responsible. In England it has been found necessary to provide living quarters for the men of the emergency crews, but such quarters are occupied only during times of intense bombing.

Distribution System

Except in the very small water works, the distribution system should be divided into divisions for maintenance and emergency repair operations. Each division is in charge of a foreman who directs all work in his area, even in emergency when gangs are moved in from other divisions. Each division should have its own equipment and supplies. If one division is blitzed, then adjacent divisions come to the rescue. If the supply is totally cut off from the area, the crew makes provisions to deliver about 25 to 30 gallons of water per day to each family from portable tanks. Loud speakers are used to notify those living in the area when the water tanks will pass down each street. In London it has taken a week to relay even as little as 72 feet of 18-inch main when the area was being constantly bombed.

In the United States it will probably be possible to secure W.P.A. labor for the repair of bomb damage, when and if it comes. A repair crew of this nature often must consist of about 75 men sometimes more. These men could be organized to work under the direction of the water works foreman. For ordinary maintenance, the crews should consist of not more than five men, but in emergency they must be quickly expanded in numbers. A large number of simultaneous breaks will require effective organization plans. One feature of such plans is quick transportation for men and materials from one division to another.

To meet the demands of war, the pipe system must be designed in such manner that no single area is entirely dependent upon a single water main. This not only calls for much duplication of pipe lines, pumping equipment, and storage facilities, but also for proper interconnections in the system. This is especially true of the industrial and commercial areas.

If the industrial area is devoted to defense manufacturing of any nature, it is particularly subject to bombing, and reinforcement of mains is essential. This requires many extra valves and hydrants. Any reinforcements recommended by the fire underwriters should be made. Many systems contain weak spots, where it is impossible to get required fire flows. This is due to insufficient pipe capacity, or in some cases, to the need for having the water mains cleaned and restored to original capacity. These weak spots can be detected easily by conducting ordinary hydrant flow test surveys, which are quite simple and inexpensive.

In England a policy of dispersal is followed in laying out the routes of water mains. Several mains, all laid along different routes are used to conduct the water to the areas of use. These are frequently interconnected, proper valves being a necessary feature. These mains have such strength, and are so inter-connected, that one or more large feeders may be rendered useless without serious impairment to the supply. English cities find this arrangement a great asset.

It is necessary to study your distribution system thoroughly to determine areas or points of inadequacy, and to plan proper strengthening. Any or all of the following may be required: additional storage, new mains, cleaning of old mains, elimination of dead ends, installation of extra valves and hydrants, and other like reinforcements. Small mains in built up areas must be replaced with larger mains, but by judicious investigation and designing, it is often possible to select one new water main which will give adequate capacity to a weak district.

Sabotage

It is unlikely that the greater part of the United States will ever experience indiscriminate and widespread bombing; but sabotage will occur to every water works unless careful plans are taken to prevent it. This will generally be the work of sympathizers, and the damage may not be great, but such cannot be anticipated. Willful contamination is the thing to which most thought has been given. The public is greatly concerned about what would happen if poison gas or bacteria were to be placed in the reservoirs; but this method of attack, while possible, is not highly dangerous because it would require far more poison gas or bacteria than could be supplied, except under very favorable conditions. The subject is very extended, and the handling and detection of war poison gases requires expert chemists; therefore it will not be treated further in this paper.

Records and Maps

Emergency crews are almost helpless without fully complete and accurate records and maps. These maps must show every feature of the distribution system, and the foreman of each division must have a complete set for his confidential use. These maps must be fully up to date at all times. From the maps, the foreman knows the exact location of all valves, by-passes, cut-offs, etc., of the buried underground structures which otherwise might be impossible to find. The information contained in the maps must not be broadcast. In the interest of safety complete sets should be kept in at least two different locations.

Hydrants

Many additional hydrants must be installed if the most severe conflagration conditions are to be fully coped with. During fires, hydrants are very vulnerable to sabotage, because of the ease with which they may be tampered with; it being not uncommon in England to find hydrants flowing full streams, many blocks from the actual bomb fires. In some cases the saboteur did not use a wrench, but resorted to more effective methods, such as backing a truck over the hydrant, doing damage which could not be repaired easily. To cope with such situations, a valve should be placed on each hydrant feed line. Hydrants must be regularly inspected and hydrant guards organized, which units can be quickly transported where most needed.

Cooperation—Conservation —Communications

No water works can effect quick repairs unless there is close and active cooperation with the other city departments, and provision should be made to draw upon all corporate resources. Similar cooperation should be maintained with other water works in the state.

Water will not be available for fire fighting if conservation is not rigidly practiced in eliminating leakage and wastage from the system. This will require regular surveys, but their cost will generally be fully justified.

To get orders and communications to the emergency crews it is necessary to work out the communication facilities which are to be depended upon. In the larger cities radio has much value, especially if provided with independent power facilities. In England great dependence has been placed in telephone and special messenger service equipped with bicycles, motor cycles, and autos. If the system adopted is not completely dependable, auxiliary systems must be provided, so that the availability of crews to the supervisor will be prompt.

Conclusion

Preventing pollution of water after it has entered the system requires that those in charge have fundamental knowledge of many subjects, and that every maintenance and operation procedure be thoroughly understood. In other words, the operation in war time should follow what is good practice in time of peace, with the exception of the required speed factor. All eventualities must be anticipated and a proper plan drawn to prevent later disaster. It is not pessimistic to keep prepared for any emergencies which may arise. It is better to take many probably unnecessary precautions than to have neglected what will prove to be a vital safeguard when the emergency comes.

"Concrete Pipe Lines"

A Handbook and Engineering Text

To our desk has come a rather extraordinary specimen of promotional literature, prepared at great expense for limited free distribution by the American Concrete Pipe Association.

This 6x9 inch publication of 301 pages, compiled and edited by M. W. Loving, an experienced Sanitary Engineer of many years' service as Secretary of the American Concrete Pipe Association, constitutes both a handbook on concrete pipe and its uses and an engineering text on hydraulics and sanitary engineering design.

"Concrete Pipe Lines," handsomely bound in simulated red-morocco, is profusely and expensively illustrated with engineering charts, diagrams and photographs of applications of concrete pipe in sewers, outfalls, drains, culverts, etc. Some idea of the value of the book as an engineering text and handbook can be had by stating that Chapter I, "The Flow of Water in Concrete Pipe Lines," is a contribution of Prof. J. E. Christiansen of the Univ. of California, which includes interpretations of the more important hydraulic formulas and supplies, highly useful diagrams and alignment charts for conversion of hydraulic data in solving various problems. Dr. Maris of Penna. State College is another contributor of note. And others are Prof. Chas. Gilman Hyde and A. M. Rawn.

Individual chapters deal with sewer construction in open cut, tunnel and sub-aqueous outfall sewers. Of particular interest to many will be those relating "The History of Sanitary Engineering" and reviewing the record of "Concrete Pipe in American Sewerage Practice." "Sewerage Systems" (design and maintenance practices) is another section deserving high commendation. Then follow many effectively picturized typical and outstanding sewerage projects employing concrete pipe. The final sections deal with the design and construction of culverts and drainage systems.

From the foreword through the appendix of 29 pages of A. S. T. M. specifications we can find nothing but praise for this remarkable job of compilation, illustrating, editing and mechanical production of *"Concrete Pipe Lines."* It will prove worthy of space in any engineer's library.—L. H. E.

OHIO SECTION'S FOURTH CONFERENCE ON W. W. MANAGEMENT

A Report
By JOHN S. GETTRUST
Supt. of Filtration
AKRON, OHIO

Chairmen

F. P. Fischer, Distr. Mgr., Wallace & Tiernan Co., Cleveland (the retiring chairman).

E. E. Smith, Supt. Water Works and Sewerage, Limo, Ohio (the new chariman).

ON MAY 14 and 15 at the Commodore Perry Hotel, Toledo, Ohio, 148 members and guests registered for the Fourth Annual Conference of the Ohio Section of the A.W.W.A.

Vice Mayor Roullet of Toledo gave the address of welcome.

R. W. Furman, Water Commissioner of Toledo, read a paper describing their new Lake Erie Water Supply System, consisting of the intake, crib and conduit, low service pumping station, Lake Erie pipe line, filter plant, covered filtered water reservoir, high lift or main pumping station combined elevated wash water, supply and surge tank and the trunk main across the city. The filter plant covered in part in an article in the April issue of W. W. & S. Various heads of departments under Mr. Furman contributed by describing the work of their divisions of the Water Department.

Harry E. Jordan, Secretary of the A.W.W.A., opened the afternoon discussion with an address on "The Part the A.W.W.A. Can Play in the Present Emergency." He explained priorities and their effect on the water works man.

The Association has been of great help in the present emergency to water works men not in the Association.

It is advisable for employes of water works not to join any branch of the Civilian Defense, since they must be free to obey directions from their superiors in the water works.

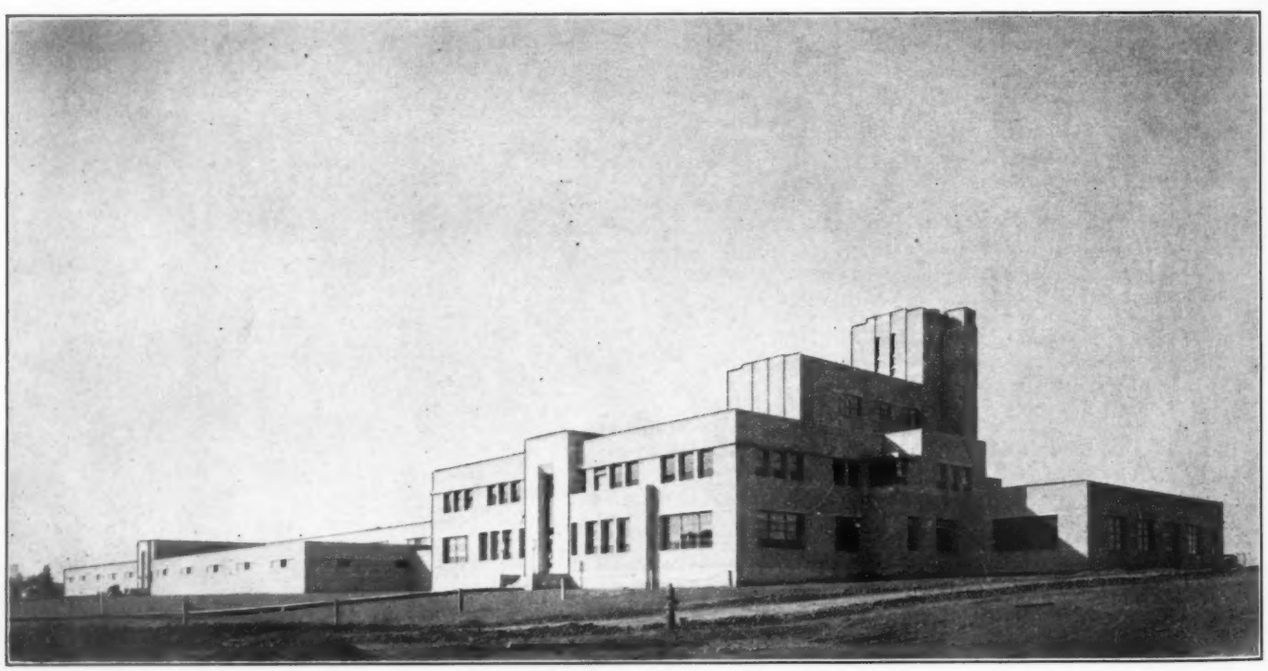
Order P146 restricting pipe line extensions came up for considerable discussion.

Directors

Wendell R. La Due, Supt. and Ch. Engr., Division of Water and Sewerage, Akron Ohio (completing his term).

Wallace W. Moorehouse, Supt. Dept. of Water and Sewerage, Dayton, Ohio (the new director).

F. H. Waring, Chief Engineer of the State Department of Health, had a paper on the protection of "Water Works Facilities in Wartime"; it was read by Mr. Wilson Knox, assistant engineer of the State Department of Health. This covered protective lighting, guards, the availability and completeness of maps or drawings of distributing piping and valves, inventories of replacement parts and conditions as found at va-



Toledo's New Filtration Plant.

rious plants throughout the state by inspectors from the Health Department.

F. B. Thomas, Deputy Supervisor, Bureau of Inspection and Supervision of Public Offices, read a paper entitled "The State Examiner Looks at a Water Works." He deplored conditions sometimes found in municipal plants where records were inadequate and did not show whether the water works were making or losing money until the examiner had completed his work.

R. D. Scott, Chemist, State Department of Health, read a paper on an improved method for the determination of phenols, a copy of which may be obtained by anyone interested sufficiently to request it from the Ohio State Department of Health.

James E. Specht, Superintendent of Utilities, Orrville, Ohio, told about their experiences with the Palmer Filter Agitators in connection with their lime soda softening plant. This device has been of considerable benefit in their plant.

A discussion followed of various types of surface washing devices, particularly the Baylis and the LaMar as used at the Detroit plant.

A. E. Kimberly, Consulting Engineer, Columbus, Ohio, read a paper on "Problems Peculiar to Ground Water Supplies."

The paper stated that resistivity tests by electrical methods were of much value and the cost is justified on important projects where relatively large volumes of ground water are required. The services of experienced physicists and geologists are essential. Test wells and pumping tests are important. Observation wells are necessary to permit estimates of probable production.

Reference was made to a useful porosity formula adapted to American conditions.

Several methods of cleaning clogged strainers and wells were discussed, including acid and chlorine treatment.

General specifications covering the drilling and equipping of wells were given. Specifications for wells should limit drawdown to insure 100 per cent effective screen area under all conditions.

Well yields vary approximately as the ratio of the logs of the diameters of the wells.

The importance of awarding contracts to well drillers of experience and demonstrated skill was emphasized.

Fuller Award Recipient
Hayes R. Kuhns, Distr. Mgr. The Leadite Co., Killbuck, Ohio.

The final paper of the session was that on "Substitute and Alternate Materials for Service Pipe," given by E. E. Smith, Superintendent of Water and Sewerage, Lima, Ohio. In this interesting paper he compared the cost of each material and presented its good and bad characteristics. (Mr. Smith's paper will be printed in full in our next issue.—Ed.)

Secretaries
Thos. R. Lathrop, Ass't Engr., Ohio State Dept. of Health (who this year retires as Section Secretary after a laudable term of service), and Harry E. Jordan, Exec. Sec'y of A.W.W.A. (who thinks the Ohio Section has what it takes).

Fuller Award to Hayes Kuhns

The evening session was a banquet served in the hotel with Chairman F. P. Fischer presiding. At this meeting the George W. Fuller Memorial Award was presented to Hayes R. Kuhns, of the Leadite Co., for his interest and work in behalf of the Ohio Section and the Association. This award, which proved very popular with the members, is believed to represent the first time that the Fuller Award has been made to a manufacturer's representative.

Judge Harvey G. Straub of Toledo gave a humorous and witty talk that kept the members roaring with laughter. The entertainment closed with a show, the "All American Revue."

The new officers elected were:

Chairman—E. E. Smith, Sup't. of Water and Sewerage, Lima, Ohio.

Vice Chairman—Harvey P. Jones, Consulting Engineer, Toledo, Ohio.

Trustees—Paul Cook, Sanitary Engineer, Painesville, Ohio; Carl Eberling, Sup't. of Water, Cincinnati, Ohio; L. T. Fawcett, Chief Engineer, Mahoning Valley Sanitary District.

Secretary-Treasurer—L. J. Hoffman, Office Manager, Akron Water Works.

A.W.W.A. Director—W. W. Morehouse, Director, Department of Water and Sewerage, Dayton, Ohio.

W. R. LaDue, Sup't. and Chief Engr., Division of Water and Sewerage, Akron, Ohio, read a paper on "The Need for Good Management of Municipal Water Works."

The water works profession will do much to improve its own status if it can effect a better top management. Too often, public opinion rules that the water works manager is doing a routine job in handling daily occurrences and that a plant, once started, grows of its own initiative. This then must give way to the true facts which dictate that good management will result only when continuing policies are allowed to develop and to thrive. The results of such policies definitely are adequate facilities; good operation; practical maintenance; logical replacement and expansion; sound fiscal methods; satisfying public service; reasonable provision for the future and all-round efficient administration. Present and future needs and problems must be conducive of and met by careful, economic and sound planning, both as to design and financing. In other words, sound management cares for the needs of the present and protects and insures the hopes of the future—a truly honorable undertaking, worthy of the water works profession and a challenge to all so engaged.

O. F. Schoepfle, Supt. of Filtration, Sandusky, had a paper on "Plant Management Problems." He outlined the technical knowledge and skill required to intelligently operate water works equipment.

N. J. Humason, Supt. of Filtration, Elyria, Ohio, read a paper on the "Preparation, Laying and Sterilization of Water Mains." He stressed keeping mains clean during laying operations, preventing trench water backing into mains. Using about 25 p.p.m. of available chlorine and period of sterilization of 5 to 7 days is practiced in Elyria.

The Retiring Chairman and Mrs. Fischer of Cleveland.

He reported successful sterilization of mains using hydrated lime producing causticity of a degree considerably higher than that used in water softening. The sterilizing effect of causticity does not seem to be voided or blocked by some materials which seem to interfere with the action of chlorine. A contact period of 10 days or more with lime is recommended.

The discussion brought out the opinion that 50 to 100 p.p.m. residual chlorine and a 24 hour contact period should suffice in most cases to produce sterilization.

A. E. Griffin, Chemist, Wallace and Tiernan Co., gave an interesting talk on the determination of high chlorine residuals. He stated that using the ortho-tolidine method enough of the O. T. must be used to give correct colors. A good field procedure would be to use equal mixtures of O. T. and water sample for residuals in the 50-200 p.p.m. range.

He also gave a method for preparing the ortho-tolidine solution that overcomes the usual difficulty encountered in getting the O. T. into solution. He recommends adding 1.5 grams of O. T. hydrochloride to 800 ml. distilled water. When completely dissolved, add 200 c.c. of concentrated HCl to make one liter of solution.

The morning session closed with two talkie movies, one showing the construction and installation of the Stone Canyon Reservoir Supply and Outlet Lines and the other was titled "Join the A.W.W.A."

E. B. Evans, Batchelor Chemist of the Cincinnati Filter Plant and "Friend." The day after it was Mr. and Mrs. E. B. Evans. She was Mary Wenninger of Toledo.

In the afternoon the members and guests were taken for a tour of the new Toledo water works. The low lift pumping station, high lift station and filtration plant were inspected.

Operating Floor of Toledo's New 80 M.G.D. Filter Plant

LOW CONSTRUCTION COST

With

"CHICAGO"-EQUIPPED ACTIVATED SLUDGE PLANTS

"Chicago"—equipped Activated Sludge Sewage Treatment Plant at one of the largest airplane factories in the country. Note the simple box-shaped structures and common-wall construction. The nest of tanks in the left foreground are for pre-aeration, primary settling, aeration and final settling. The digestion tank is at the right, and the sludge beds are in the background. This is a 0.5 M.G.D. plant. Albert Kahn, Architect; Russell & Axon, Engineers.

STRUCTURAL ADVANTAGES . .

1. **Characteristic low head-loss** through Activated Sludge Plants simplifies construction.
2. **Lift station construction eliminated** at many Activated Sludge Plants because of low head-loss required.
3. **Best footing conditions** at any site can be taken advantage of, because all structures of Activated Sludge Plants are at approximately the same elevation.
4. **Occupy smaller space** than other types of plants for complete treatment.
5. **Simple box-shaped structures** can be nested to take advantage of common-wall construction.
6. **Construction of aeration tanks simpler** than secondary structures of other processes for complete treatment.
7. **Aeration equipment is simple** and easily installed.

SEND FOR OUR LITERATURE ON THE ACTIVATED SLUDGE PROCESS

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SUCCESSFUL "CHICAGO"-EQUIPPED ACTIVATED SLUDGE PLANTS SINCE 1936
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LEADITE

The Pioneer Self-Caulking Jointing Material for Bell and Spigot Water Pipe

Products

LEADITE and the following tools and equipment for use with LEADITE:

BRAIDED JUTE, JOINT RUNNERS, GASOLINE and WOOD BURNING MELTING FURNACES, POURING LADLES, POURING POTS, YARNING IRONS and METAL POURING GATES.

Description

Leadite is principally used for making joints in cast iron bell and spigot water mains; is shipped in powder form in sacks containing 100 pounds.

Users

Water works superintendents, engineers, contractors, mines, railroads and industrial plants all over the world use Leadite. Thousands of miles of pipe jointed with Leadite are in service.

Method of Use

The joint space is first "yarned" and the Leadite is melted and poured into the joint, but requires no caulking. Leadite melts at approximately 250° F. Lead melts at approximately 620° F.

Comparative Quantities

One hundred pounds of Leadite are equivalent to approximately four hundred pounds of pig lead based on the joints being made the same depth with either material. It will be easy to figure the approximate quantity of Leadite required for any given quantity of pipe by referring to our Reference Table, copy of which we shall gladly send to you upon request.

Comparative Cost

Under normal conditions, the economies effected by the use of Leadite save approximately 50% to 75% over the method which requires caulking owing to the saving effected in material and labor.

Saving

Because Leadite saves on the items of caulking charges, digging of large bell-holes and reduces cost of trench pumping to a minimum. Leadite eliminates most every superfluous operation in jointing cast iron water mains, thus permitting the work to be completed with the least amount of effort.

Tools

As no caulking is required, fewer tools are needed.

No Caulking

Leadite joints require no caulking because Leadite adheres to the pipe from the yarn or jute out to face of bell, making a watertight bond. However, a Leadite joint may be melted or cut out at any time if desired in making connections, etc.

Durability

Leadite has been tested and used for more than 40 years and experience has proven that Leadite joints improve with age.

Expansion and Vibration

Leadite is used with excellent results under railroad tracks, highways and over and under bridges where severe vibration has demonstrated the value of using Leadite on this class of work.

Utility

Leadite is very easy to handle. It is used on all sizes of pipe from four to eighty-four inches in diameter and under all conditions and pressures encountered in water works construction.

Electrolysis

Leadite resists electrolysis.

Damage Suits

Claims for damages caused by joints blowing out are reduced because Leadite joints, if properly made, will not blow out under any pressure common in water works construction.

Transportation

Considerable freight charges are saved because Leadite is light in weight. This also means a saving in cartage and handling on the work because you move approximately one-fourth the weight of jointing material.

Delivery

We make prompt shipments of Leadite in any quantities from stock.

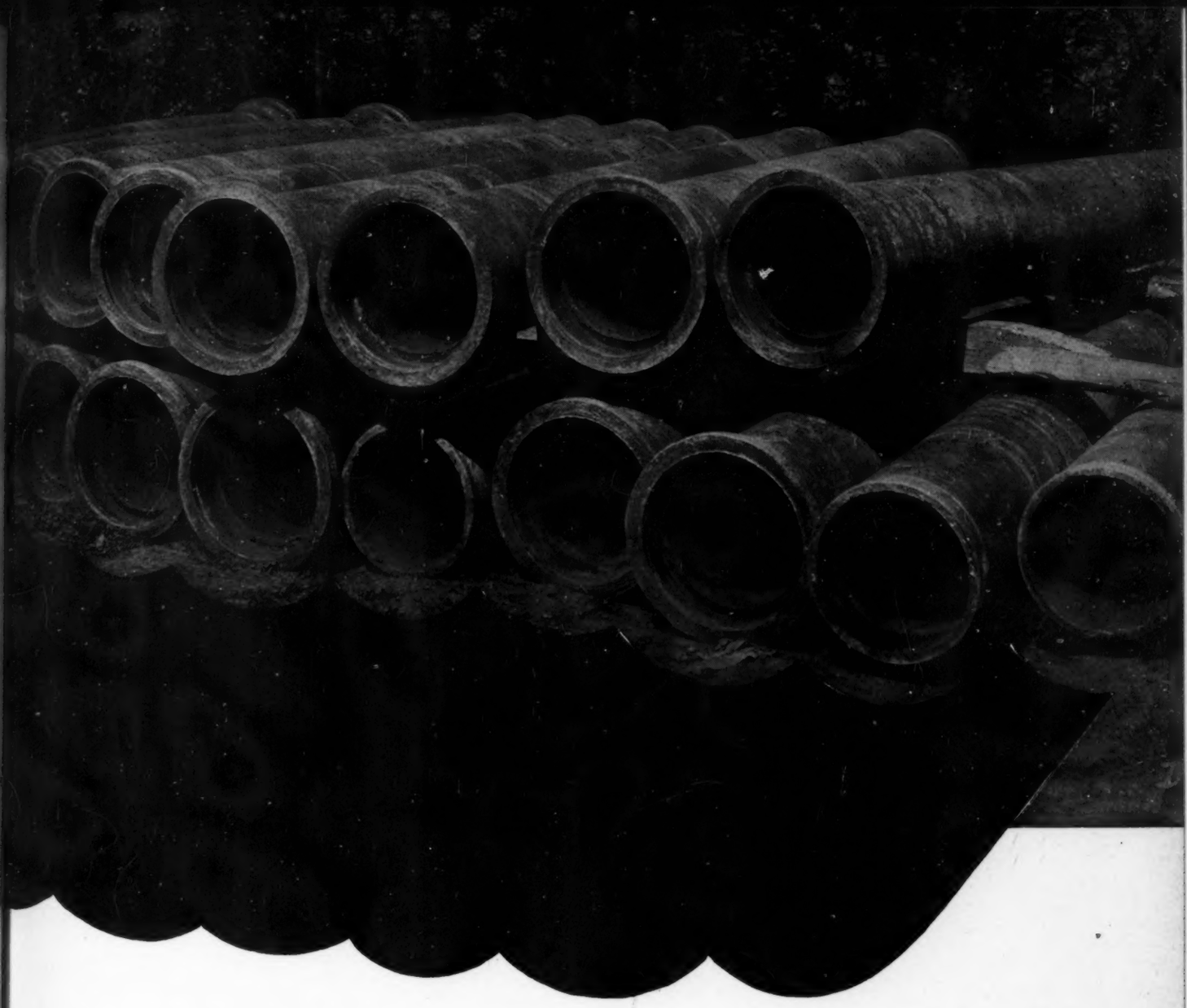
Fuel

Saves fuel because you melt approximately one pound of material instead of four, and less heat is required to melt Leadite than is needed to melt lead.

Be sure it is Leadite and not something "Just as Good"

THE LEADITE COMPANY
Girard Trust Company Bldg., Philadelphia, Pa.

No Caulking



CAST IRON MAINS, when abandoned or re-routed, can be salvaged and re-used, thus saving money for the taxpayer. For example, the 16-inch cast iron pipe shown above had served the City of Roanoke, Virginia, for 50 years in its original location. Last year it was removed to make way for a new armory and relaid in a new location to serve out its full life of more than a century.

We have on file many records of old cast iron mains which have been taken up and re-used, or sold to other cities for re-use, or sold as scrap. It is impossible to foretell future requirements or population shifts in metropolitan cities but any public official can be sure that, when water or sewer mains must be abandoned or re-routed, the pipe can be salvaged or re-used, if it is cast iron pipe.

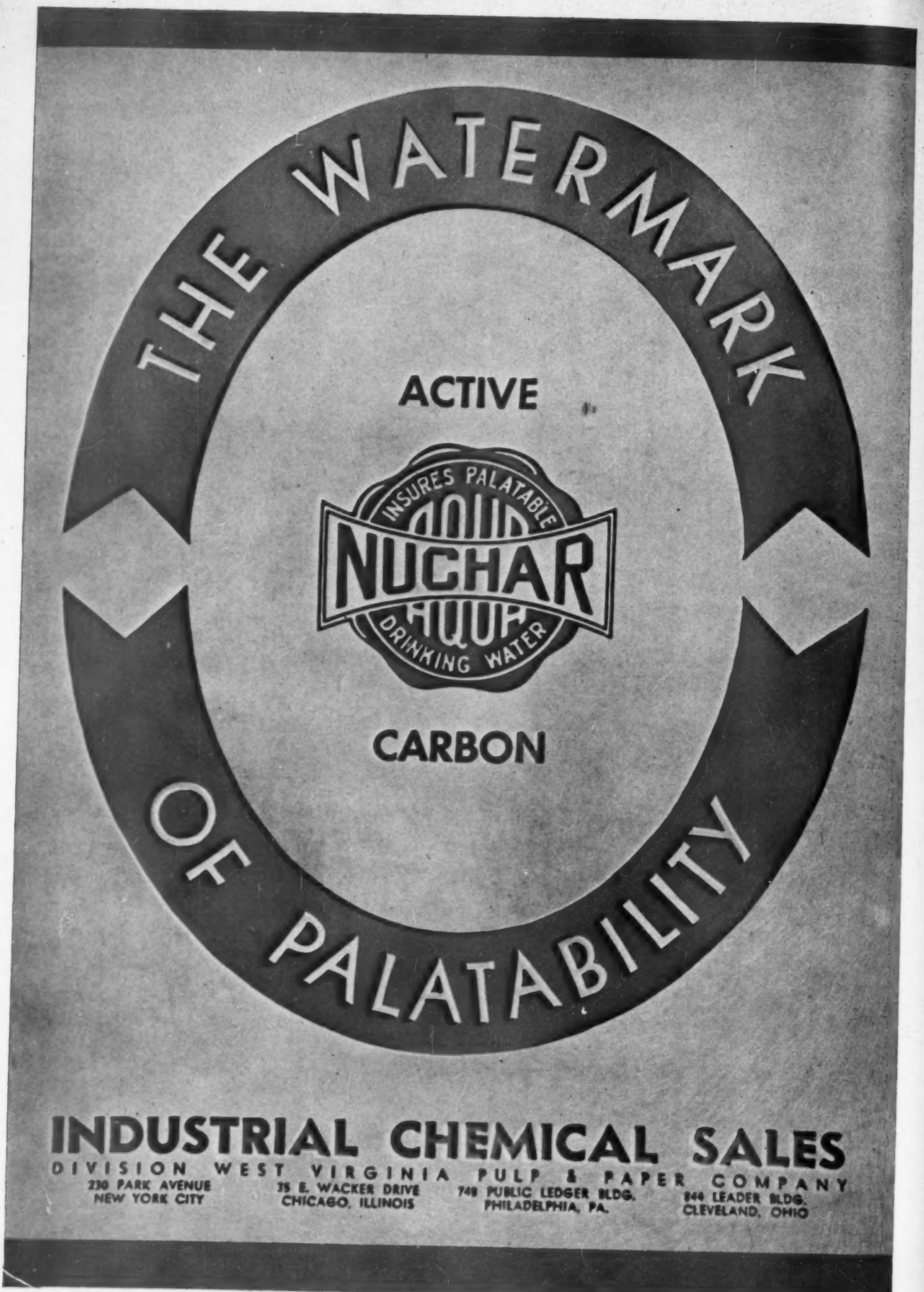
Pipe bearing this mark is cast iron pipe

TRADE MARK REG.

Available in diameters from 1¼ to 84 inches.

CAST IRON PIPE RESEARCH ASSOCIATION, THOMAS F. WOLFE, RESEARCH ENGINEER, 1015 PEOPLES GAS BUILDING, CHICAGO, ILLINOIS

CAST IRON PIPE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PHILADELPHIA, PA.
944 LEADER BLDG.
CLEVELAND, OHIO

EXPERIENCES WITH CALGON TREATMENT AT BRISTOL, CONN.

I. LAIRD NEWELL
Chemist, The Henry Souther Engineering Co.
HARTFORD, CONN.

DURING the past year the water supplied to the City of Bristol, Conn., has been treated with "Calgon" (hexameta phosphate) to minimize corrosion of the distributing system.

Bristol, a city of about 35,000, obtains its water supply from five upland reservoirs located from 1½ to 8 miles from the city. In 1938 an all-steel filter plant of the Morse design was constructed and put into operation. The usual methods of water purification are used, namely, aeration, alum and soda ash treatment, followed by mixing, coagulation and filtration. The raw water from the reservoirs entering the filter plant may be characterized as soft, low in alkalinity and mineral matter.

The filtered water has been treated with lime to reduce the hydrogen ion concentration (raise the pH value), and chlorine is added to the filtered water as a precautionary measure. From the time the filter plant was put into operation in 1938 until early last year, lime was added to the filtered water to maintain a pH value of approximately 8.5. Until the trial of "Calgon" treatment, lime addition was the only treatment given to prevent "red water."

For comparison with the treated water, the following figures are of interest:

Table I

Raw Water—March, 1942

pH	6.7
Alkalinity	5 p.p.m.
Hardness	10 p.p.m.
Color	23 p.p.m.
Free CO_2	3 p.p.m.

It will be noted from the analysis that to prevent corrosion by the equilibrium method would require the use of such an amount of lime and soda ash as to materially increase the hardness and concentration of mineral matter. Since this would be objectionable not only from the industrial but also from the domestic users' standpoint, it appeared desirable to investigate the use of Calgon.

Calgon Treatment Seemed Worthy of Trial

Because of the fact that the filter plant operates on several different pumping rates, it was decided to obtain equipment for feeding the Calgon which could be adjusted to different rates of flow. Briefly, the solution of Calgon was made up in a 50-gallon earthenware crock in a concentration of approximately 12 per cent. This is equivalent to 46 pounds per 50 gallons of water. The solution is made by spraying cold water onto the Calgon, which is held in a wire basket directly over the earthenware crock. This solution is fed to the filtered water by a Wallace & Tiernan Type HEM Hypochlorinator, which delivers to the filtered water through rubber tubing. This hypochlorinator has been in continuous use since its installation and has worked with complete satisfaction.

The Author

Calgon treatment was started on March 11, 1941. The following table gives a record of the chemical and bacteriological results on selected dates before and after the application of Calgon in conjunction with the small quantity of lime already being applied.

Table II

Date, 1941	pH	Alkalinity	Hardness	Color	Bacteria 20°	Bacteria 37°	Calgon p.p.m.
Jan. 2	8.4	13	16	3	7	4	None
Feb. 7	8.1	12	14	3	16	2	None
Mar. 7	8.5	14	14	3	8	1	None
Calgon treatment started March 11, 1941.							
Mar. 13	8.5	14	14	3	17	1	2
Apr. 18	8.5	15	22	3	46	2	2
May 8	8.7	14	18	2	950	1	1.5
June 13	8.6	14	20	3	60	4	1.5
July 18	8.1	11	20	3	16	5	1.5
Aug. 7	8.8	14	20	4	6	2	1.5
Sept. 11	8.1	12	16	3	13	9	1,5
Oct. 16	7.8	8	16	3	1	0	1.5

Then on November 15th the lime treatment was discontinued and the results follow in Table II-A.

Table II-A

Date, 1941—	pH	Alkalinity	Hardness	Color	Bacteria 20°	Bacteria 37°	Calgon p.p.m.
Nov. 14	6.1	3	10	3	8	7	1.5
Dec. 19	6.1	3	10	3	0	0	1.5
1942—							
Jan. 9	6.1	4	15	3	2	1	1.5
Feb. 13	5.8	3	14	3	2	1	1.5
Mar. 19	6.1	3	10	3	2	1	1.5

In addition to the tests shown above, special examinations were made of samples of water taken at selected points in the distributing system:

Sampling Point	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
Miles from filter plant	0	2.2	3.0	3.2	4.1	4.8	5.1

Sampling Point No. 2 represents the center of the distributing system, while Points No. 3 to No. 7 inclusive are dead ends.

Table III

Results Before Calgon Treatment

Sampling Point	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
pH	8.2	8.3	8.8	8.8	....	8.8	8.7
Alkalinity	14	15	18	18	....	20	15
Color	3	3	85	100	....	50	28
Iron	0	.016	4.0	3.8	....	1.8	1.4
Dissolved oxygen.	Saturated	Saturated	....	....	....	....	....

It will be noted that the dead end samples all showed high color, due to the concentration of iron in these samples.

Table III-A

Results After One Week of Calgon Treatment (2 *p.p.m.*)

Sampling Point	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
pH	8.4	8.5	8.3	8.5	8.5	8.4	8.5
Alkalinity	16	15	14	16	16	15	15
Color	3	3	35	60	50	30	30
Iron	0	.004	.38	.36	.24	.40	.60
Calgon	1.9	1.4	.5	.7	1.6	.8	1.7

Experiences with Calgon Treatment and Results

Before going into a general discussion of the results obtained by the use of Calgon, it seems worth while to mention a few of the experiences as they occurred with its use. Directly after the original application of Calgon, which was at the rate of 2 parts per million, some disturbance appeared in the system and it was decided to thoroughly flush the pipes. It is fortunate that this was done immediately, as extremely large amounts of tubercles and other corrosion products were sloughed off the inside of the pipe and removed from the system by blowing off. If this had not been done, the tubercles and other matter might have collected in some constricted parts of the system and caused serious stoppages. After the whole system was flushed, the treatment with Calgon was reduced to 1½ parts per million.

Prior to the results obtained above, the addition of lime to the filtered water had been stopped for some time. It will be noted that, as a result, the pH values are much lower than previously. One sampling point, namely, No. 4, shows a high pH, but this is due to the effect of cement-lined pipe on the water. There was no increase in corrosion of the pipes which could be attributed to the lowering of the pH.

In order to have the Calgon reach some of the dead ends of the system in sufficient amount to prevent corrosion at these points, it has been necessary to bleed or flush occasionally.

Referring to Table II, it will be noted that directly after the treatment with Calgon, the 20° bacterial count increased to some extent, but it was possible to effectively control this by slightly increasing the chlorine dosage.

In general, the treatment with Calgon has been most satisfactory from the standpoint of corrosion of the distributing system.

The author wishes to thank Messrs. Earl and Clair Lourie of the Bristol Water Department for permission to use the data contained herein. And in the preparation of this paper, to acknowledge the helpful suggestions of Mr. James A. Newlands, designer of the Bristol plant and president of The Henry Souther Engineering Co.

Table IV

Results After Two Months of Calgon Treatment (1.5 *p.p.m.*)

Sampling Point	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
pH	8.5	8.4	8.6	8.8	8.9	8.1	8.7
Alkalinity	13	14	16	15	15	11	15
Color	3	1	22	2	11	12	18
Iron	0	0	.5	.09	.55	.35	.09
Calgon	1.5	.7	.8	.4	.3	.2	.7

These results show that the full effects of Calgon was by then reaching even the dead ends of the system, as indicated by the decreasing iron concentration and color. There does not, however, appear to be any exact relationship between the amount of Calgon found at the sampling point and the amount of iron and color.

Table V

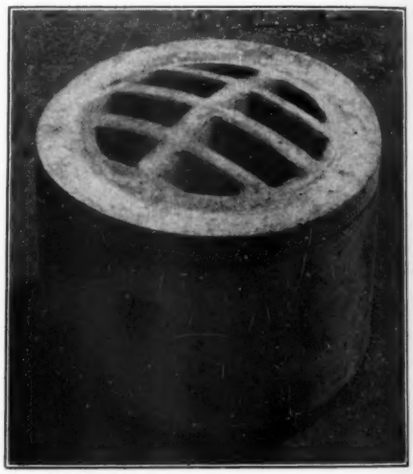
After One Year of Calgon Treatment (1.5 *p.p.m.*)

Sampling Point	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
pH	5.9	5.9	6.5	8.6	6.1	6.9	6.7
Alkalinity	2	4	9	13	6	11	9
Color	2	1	22	7	15	8	23
Iron	0	Trace	.45	.10	.25	.20	.40
Calgon	1.6	1.2	.6	.2	.2	.4	.2

Concrete Catch-Basin Grates

Designed to Save Critical Materials

The need for conserving critical materials has led to the redesign of many products ordinarily made of steel and cast iron. The accompanying photograph illustrates what has happened by redesigning catch-basin grates in concrete with the minimum of steel—in this case only about 2½ lbs. contained in the ¼-in. reinforcing bars used.



The photograph shows a catch-basin grate designed and being built by the Nelson Concrete Culvert Co. of Champaign, Ill. Its use is restricted to areas where it will not be subjected to vehicular traffic, such as off-the-road and field drainage. It has been approved by the Division of Highways of the Illinois State Department of Public Works and Buildings and has been adopted by a number of Illinois counties. The grate replaces the highway bureau's standard No. 8 grate formerly made of cast iron.

The grate shown is said to cost about $7.50 each, as compared with approximately $13 for the grate of cast iron formerly used.

INSTALLATION OF PALMER FILTER BED AGITATORS

A Method Which Involves Simplification of Construction and Reduces Costs

By SAMUEL H. MITCHELL
Chief Operator
FILTRATION PLANT
ALLENTOWN, PA.

PALMER Filter Bed Agitators have been installed in the filters of the Allentown, Pa., Filtration Plant. Because the filters are approximately 20x22 ft. in area, and being equipped with concrete filter troughs, the best method of installing the piping for the support of the agitators constituted a problem. Due to the fact that the supporting pipe could not be fastened to the troughs in any way, it was necessary to anchor it in the four walls. This was done by attaching 2½ in. pipe flanges to the wall with Tampin anchors.

The Author

The agitator arms used were 19 ft. 6 in. in length with a 2½-in. pipe thread on the revolving joint. The piping in the filters was installed in the form of a cross. One pipe extends from side to side of the filter with a tee in the center. Beneath this and at right angles, the other pipe extends from the rear wall to the front wall. This lower pipe has a cross at the center directly beneath the tee of the upper pipe. The lower pipe serves the dual function of support member and as the pressure water supply line to the agitator. (See Fig. 1.)

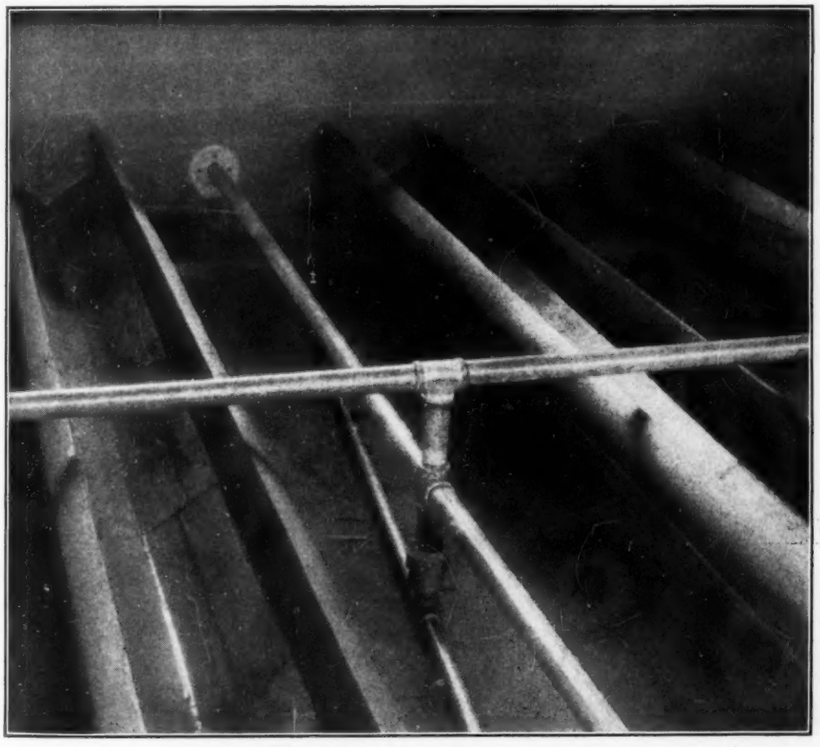


Fig. 1.—Palmer Filter Bed Agitator Installation.
Showing Method Employed at Allentown, Pa. Note center hook-up and anchor on rear wall of filter.

The pressure water line was connected to a tee which was connected to a flange on the front wall. Next to the tee was installed the valve with which the agitator is operated. (See Figs. 2 and 3.) An extension has been placed on the valve stem so that the handle is within easy reach of the operator.

The tee and the cross were connected with a nipple, and the revolving head and arms of the agitator were connected to the cross with a nipple long enough to allow the sweep arms to swing freely under the troughs. In order to seal the open ends of the support pipes that were used for the water supply line to the sweep, it was necessary to blank the close nipple between the flange and the tee at the front wall and the nipple between the tee and the cross in the center, and also the pipe extending from the cross to the rear wall. This was done by welding a metal disk in the end of these pieces.

Expensive Union Joints Eliminated

After installation of the first agitator was completed, a checkup of the cost revealed that the two 2½-in. unions used ran the amount up rather high. Therefore, on the next installation it was decided to use some other type of joint to take the place of the expensive unions. The type of joint decided upon was a "long-screw," an item well known to the pipe fitting trade and listed in most plumbing supply catalogues. While a neater long-screw joint can be made with machine shop equipment, it is still possible to make an efficient long-screw with ordinary pipe fitting tools.

Five long screws were used in each filter. One was screwed in the flange on the rear wall, one in each of the flanges on the side walls, and one in the valve on the front wall. These so-called screws were 12 in. long, one end being a standard thread and the other a long thread of 5 in. An ordinary coupling was cut in half cross-wise, and one of the pieces

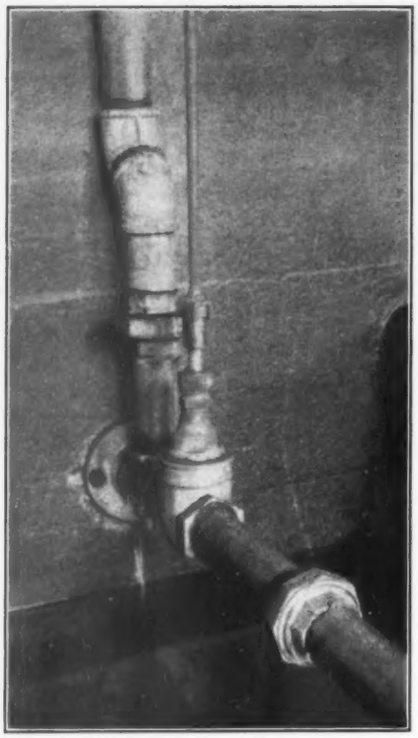


Fig. 2.—High Pressure Hook-up in First Installation
Made with Expensive 2½" Unions

screwed on the long thread. This was followed up with a standard coupling, and both were turned on until the end of the nipple and the end of the coupling were flush. The pipes in the filter were connected to the long screws by backing the standard coupling off the long screws on to the pipes until they were tight. Then some lamp wick and white lead were put between the standard coupling and the half coupling, and the half coupling was drawn up tight against the standard coupling.

The fifth long screw was used as a make-up piece on the high pressure supply line, and although the pressure on this line is 105 pounds, no leaks have occurred on any of the long screws used on these lines.

Comparison of Costs

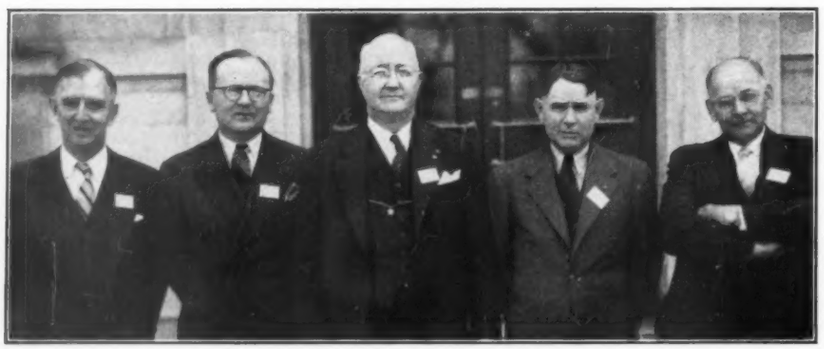
In order to show the savings effected by employing the long screws and standard couplings in place of unions, the following list prices were taken from a well-known plumbing supply catalogue.

Quantity	Material	Price
1	2½ in. galvanized union	$4.80
1	2½ in. galvanized long screw	3.10
1	2½ in. galvanized coupling	.55

It requires one and one-half couplings to make a long-screw joint. The length of pipe used would have to be used regardless of the type joint required, so the cost of a home-made long screw is about $.78, plus the labor cost for cutting the threads, which in this installation was done on a pipe cutting machine and did not take very long. The reason for using a long screw on each wall was to make it an easy matter to remove the pipe completely or in part if the necessity should ever arise to work in the filters.

This set-up owes its origin to a desire for economy and efficient operation as well as simplicity in construction.

Fig. 3.—High Pressure Hook-up in Subsequent Installation
Made with Inexpensive "Long-Screws" and Standard Couplings.



Arkansas' Twelve Year Men

Attending the recently held 12th Annual Arkansas Water and Sewage Conference at Fayetteville, Ark., were six "regulars" who have to their credit a perfect record of attending all of the twelve conference meetings. From left to right these twelve-year men are (1) *Harrison Hale, Head of Dept. of Chemical Engineering, Univ. of Arkansas;* (2) *L. A. Jackson, Manager Municipal Water Dept., Little Rock, Ark;* (3) *Egmont S. Smith, District Manager, Neptune Meter Co., Dallas, Tex.;* (4) *Henry Nunn, Supt. Water Department, Van Buren, Ark.;* (5) *W. R. Spencer, Head of Dept. of Civil Engineering, Univ. of Arkansas. (A. H. Ullrich, Chemical Engineer, Water Dept., Fort Smith, although not in the picture, also has attended all twelve meetings.)*

Quimby Leaves Racine for War Duty

Walter Peirce, manager of Racine (Wis.) Water Dept., writes that Frank K. Quimby, for the past 12 years Construction Engineer in the Racine Department, has been "loaned for the duration" for service to the War Department. He is now Engineer in Charge of Maintenance and Repairs of Water Works, Sewerage and Services in the 6th Corps Area, with headquarters in Chicago.

E. Miles Griffith, until now Assitant Engineer in the Racine Water Dept., has been made Distribution Engineer, assuming the duties performed by Mr. Quimby.

SEWAGE TREATMENT AT APPLETON

With Particular Reference to the Preparation and Utilization of Air Dried Sludge

By C. O. BAETZ
Superintendent
SEWAGE TREATMENT WORKS
APPLETON, WIS.

AS CIVILIZATION has progressively given us more and greater industries and has enhanced the comforts and conveniences of living, it is but natural that many wastes and offensive by-products have resulted, with annoying problems in their disposal.

The Fox River had become increasingly polluted during the last few decades, and its low oxygen content has been unable to carry the load, to say nothing of supporting fish and plant life. The program of construction of sewage plants along this river has therefore, been timely and prudent.

The Situation at Appleton

The City of Appleton has a population of 30,000; with the additional suburbs the total domestic load will approximate 34,000 people. The sewage flow is estimated at 4¼ M.G.D. The industrial load adds another 5 M.G.D. This comes from pulp and paper mills, iron works, woolen mills, toy factories, breweries, woodworking plants, and milk condensories.

The Appleton interceptor system is eight miles long, with the south branch three miles and the north branch totaling five miles. An inverted siphon of 15 and 30-inch pipes conveys the sewage from the north to the south side line. The entire system operates on gravity flow, except for two small lift stations, one along the valley on the south side and one in the northwest part of the city. The interceptors have a 54-foot drop from point of origin to the Treatment Plant. The storm water flow raises the total flow to the plant as high as 33 M.G.D. rate, but 18 M.G.D. is the maximum flow for operating if settleable solids retention is to be satisfactory.

The Author

The Appleton Sewage Plant was designed for a 10 M.G.D. flow. The storm water flow reduces the settleable solids removal from 99.5 per cent on normal flows to 90 per cent on these storm days. The flow through the plant can only reach 22 M.G.D.; the balance by-passes after screening and grit removal.

Screenings Removal and Grinding

The ½-inch bar screen openings are raked by a Link Belt scraper. The scraper and grinder are set to operate automatically with time clocks. The screenings are flushed into a Gruendler grinder and dropped into the sewage flow after grinding. The grit chambers may be operated singly for low flow periods. The inorganic material is lifted to the operating floor by screw conveyor and dropped into cans for removal to dumping grounds.

Chemical Treatment

The chemical building houses the dry feed machines, chlorinators and gas engine driven blowers. "Ferrisul" (ferric-sulphate produced by Monsanto Chemical Co.) has been used as the coagulent for the past three years with very good results.

The flocculator air grid section covers approximately one-half of the 64x31x15 foot tank. Four paddle wheels complete the agitation.

The two settling tanks are Dorr Co. design—70 feet in diameter with 13-foot sidewalls. The effluent from these clarifiers passes through a contact tank 55x35x10 feet, with appropriate baffling walls.

Chlorine is added by means of two Wallace and Tiernan 750-pound machines, manually controlled. Both the influent and effluent are treated with chlorine.

Sludge Digestion

Two Chain Belt Co. "Rex" sludge pumps raise the raw sludge 52 feet to the digesters on the hill. The Appleton plant is blessed with over digestion capacity. Four 70x31-foot digesters with P. F. T. floating covers give us cause for thanks. We use the two north tanks for digestion and the two on the south for winter storage. All are equipped with heating coils. Gas, used for heating and power purposes, has reached 70,000 cubic feet per day. This volume of practically 2 cu. ft./day per capita served is the result of industrial wastes in the sewage.

The sludge control building is located between the tanks and is a 30x24 structure. It houses the digester heating plant, sludge pumps, gas meters, fresh water flushing system and other miscellaneous equipment.

The sludge beds are 375x200 feet

The Royer—a Little Machine with Big Ways.

"Pile Run" *"Easy Pull"* *"Action!"*

in size. This area is divided into 20 beds. Drain tile returns the drainage water to the settling tanks for further treatment. The sludge is removed from the beds by hand and stock piled.

Sludge Preparation and Sales

When time and weather permit, the Royer Sludge Grinder is operated. Ammonium sulphate, phosphate and potash are added while grinding so that a balanced fertilizer is produced. Analysis of the fortified product shows 5.17 per cent nitrogen, 2.07 per cent phosphoric acid, and 2.10 per cent potash.

The entire output of sludge is sold either as unfortified soil conditioner or as "Appcolizer" (Appleton Community Fertilizer). Plant sales during 1941 ran to $2,271.60, but with the rainy spell and shortage of chemicals this spring, it is believed that we will not reach this figure for 1942.

Grinder Jointly Owned

The Royer grinder is owned jointly by the Park Board and sewage plant. Much of the prepared sludge is applied to parks and golf courses and very fine results are reported.

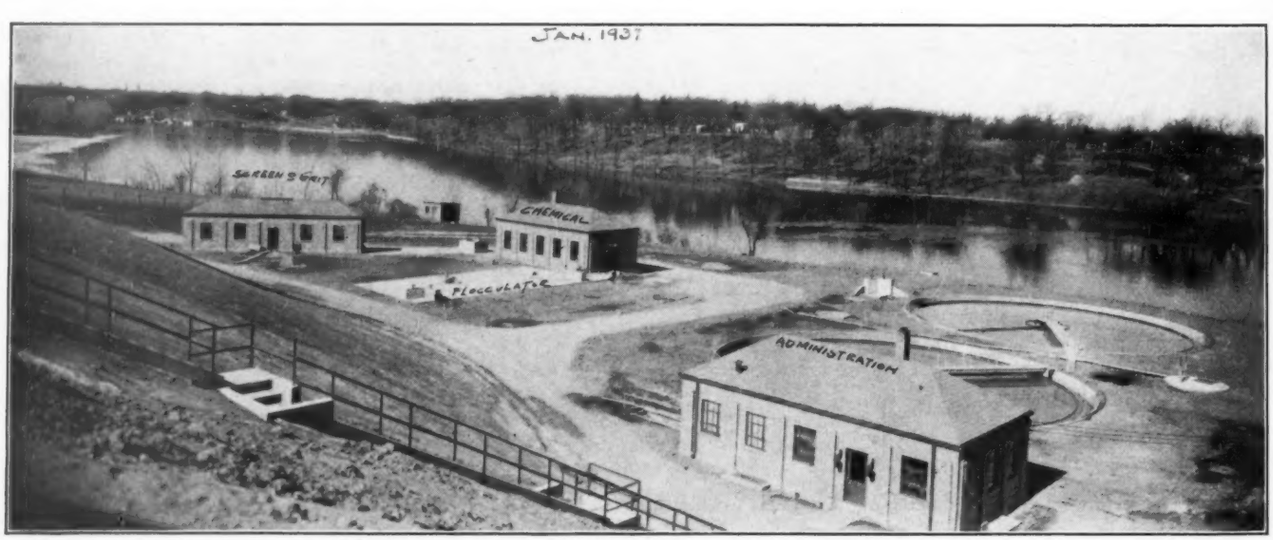
When we first started to use sludge as a soil conditioner we prepared an experimental plot where only clay soil was found. Sludge to a depth of 2 inches was spread over the area, then plowed under. Another 1-inch layer of sludge was spread over the area and thoroughly worked into the clay. This experimental section was the area around the office and clarifiers. This was seeded, and today we have one of the finest lawns in the city. Another experimental section adjoined the clarifiers, where we have a flower plot given over to tuberous type plants. Next to that are the berry bushes, where a commercial grade of fertilizer is used. Growth on the sludge treated areas is such that the bushes in two years are bearing more than the bushes in the original tract, stalks are heavier and look healthier. This year we have added sludge to the clay removed during excavation for the clarifiers, and turned it under by plowing. We hope to plant sweet corn and potatoes in this plot—truly a victory garden. The largest tomato last year was a few ounces under four pounds. A few handfuls of "Appcolizer" under each hill sure does the trick.

"Production"

The Royer grinder, when run by gas-engine, is far more flexible than by electric motor. With the engine drive there is more power, seemingly, and of considerable importance is the fact that sludge with considerable more moisture can be handled. If the sludge cake is *too* dry, we have a dust problem, but a little supernatant or city water cures this trouble easily.

That we produce a good fertilizer is proven by the smooth, velvety condition of our lawns, parks, school grounds and the local golf courses. It is by far the best soil builder that has been tried around Appleton.

Our only advertising consists of cooperation of the local press in printing news items and pictures of our experimental plots. Each neighbor soon has others using our "Appcolizer." Now, while we would not like to leave the impression that "the tail wags the dog" at Appleton, we do believe that the "tail" can and should serve a purpose, too, particularly so at this time when conservation of materials and resources, and encouragement of local war-gardening is of such importance.



General View of the Appleton Plant from the Sludge Digesters on the Fox River Bluff

WISCONSIN SEWAGE WORKS OPERATORS MEET AT WAUSAU

A Report by
R. W. FRAZIER
Superintendent, Sewerage Commission
OSHKOSH, WIS.

ON MAY 5th and 6th the Conference of Wisconsin Sewage Works Operators met in Wausau, Wis., to hear papers on and discussion of topics of a defense nature and hold round table discussions on operating problems. Fifty members and guests attended the meeting, which was opened by the Mayor of Wausau in an address commending the operators on their good work and urging them to carry on.

The meeting was a decided success in that the subjects on the program were timely and of interest to all in attendance. New members and operators of new plants received new ideas as to treatment plant operation. The emergency condition was noted in the way of travel, as most of those in attendance traveled by train and bus, and those that came in their own cars picked up others on the way.

An inspection trip was made through the Wausau Sewage Treatment Plant guided by Supt. Lawrence Manteufel. In conjunction with sewage treatment facilities, the garbage incinerator is part of the plant and so arranged that sludge incineration can be accomplished.

First aid demonstration was given by the Wausau Fire Department on the proper method used in artificial respiration, use of the inhalator and resuscitator, and the oxygen gas mask.

A special meeting of the Sewerage Works Protection Committee was called by L. F. Warrick, as chairman, for the purpose of planning and organizing the various works personnel and equipment for the emergency. The committee reports on priorities, mutual aid and plant personnel were given. Various questions were asked and discussed on the committee reports, and action was to be started at once in carrying through as a result of the reports. Maj. Wm. H. Cary Jr. of the Regional Office of the O. C. D. advised and suggested ways and means of working out the problems.

Round Table Discussions

The writer took charge of the Round table, in which the following topics came up for discussion:

1. Sludge Disposal.
2. Moisture Conditions in Plants and Effects.
3. Plant Equipment Maintenance.
4. Loading Effect Due to War Emergency.

Superintendents and operators were asked about their particular problems, and others joined in as to how they were taken care of. This method of discussion proved to be a satisfactory way in presenting the problems to all treatment works operators and gave them an idea of what others are doing.

Questions and Answers

(Leader—J. C. Mackin of Madison)

As a prelude to this session, all members were asked to submit questions in writing. The result was that interesting questions came through and the meeting was too short to answer all of them. The chairman called on various men to state what they have done to overcome the particular problem.

The questions involved referred to the following:

Gas Engine Operation and Maintenance Paints, Trickling Filters, Activated Sludge Treatment, Power Costs and Rates, Plant Protection During the Emergency, and many others.

New Officers

Officers chosen for the year are:

President—J. C. Mackin, Madison.

First Vice President—R. W. Frazier, Oshkosh.

Second Vice President—Fred Comstock, Brandon.

Secretary-Treasurer—T. F. Wisniewski, State Board of Health, Green Bay.

Technical Sessions

(President Geo. Martin Presiding)

State Committee Report on Sewerage Works Protection, by Chairman L. F. Warrick, Chief State Sanitary Engineer, Madison, Wis.

National defense was stressed in the protection of treatment works against sabotage and actual bombing. The working out of the problem for protection is to be of a local nature in conjunction with the county, state and national defense groups. More stress is to be placed in centers where defense work is being done.

Prevention against sabotage is control of personnel, unauthorized visitors, fencing and lighting of buildings and grounds, communications and policing.

As a counteraction against sabotage and destruction, a Sewerage Works Protection Committee was formed. This committee to work out plans for the protection of treatment works under the emergency conditions so that health and sanitation can continue. This group to work along the lines of defense. The problems are to be placed before the local defense committee on service and supply. Coordination of local groups to be considered on state, county and local levels.

Information as to the state level and regional level will be forwarded to the local chairman through the chairman of the committee. The work contemplated to date is the priorities schedule, mutual aid, and a so-called "lease-lend" program for the emergency. In order to have the proposed plan work out successfully, each individual is to study his own problems as to what help he needs and what help he can offer to someone in need of this help.

Reports will be sent out from time to time as progress is made by the State Committees through the State Chairman.

Sewage Treatment—Small and

Medium Sized Plants, by Ben L. Williamson, Assistant Sanitary Engineer, Iowa State Board of Health.

The need of a sewage treatment plant and its construction requires thought as to the hygienic, legal, aesthetic and economic value to the community. This involves irrigation, ice harvest, farm life, drinking water, riparian rights, etc.

The treatment plant is a plant for taking care of bacterial action and separating out the solids, and can be one of the three types, as partial, primary or secondary treatment, depending on local conditions. The advantages and disadvantages of various types of treatment and the units involved should be studied thoroughly so that plant operation can be minimized and proper treatment be accomplished without too much lost motion and control.

Operators are to stress the point to the designers of the difficulties encountered so that future work can be less complicated, with more accessability to equipment and flexibility of operation. Proper operation of a treatment plant is necessary for correct treatment, and maintenance of equipment is necessary at all times.

Sewerage works operators should be encouraged to visit various plants and attend meetings, to talk over their problems, and in so doing they will be able to solve some of their difficulties. Plant records are essential for control, maintenance, and future construction.

State Health and Welfare Program As It Relates to Defense Activities, by Dr. Carl Neupert, Assistant State Health Officer, Wisconsin State Board of Health, Madison.

A Federal level on this activity has been established. Each state to plan and work out their own program as a single pattern cannot be applied to all states. The health of the people of each state is the main objective as it affects man power. Other groups are formed for the welfare of the people, which include recreation and education.

The Health and Welfare group on state level is under the State Civil Defense Board and is divided into a number of sections. The Health and Welfare group, as its name implies, is to carry out its work at all times and in emergencies. A long time program has been worked out in this field as, for instance, nutritional benefits. Our diets may not be proportionally balanced by not containing the beneficial vitamins. Consideration should be given the common foods as milk, eggs, whole wheat bread, and green vegetables. By taking these foods in proper form, benefits are noted in that a number of aches and pains disappear. Although a number of us do not like certain vegetables as spinach, but by getting the food inside of us, the vitamins will help along. The men in the Army and Navy have balanced diets which most of us do not consider, and the result is that the men in the armed forces are physically fit for the work before them.

Sewage Treatment at Camp McCoy, by Mr. Strand, Division Engineer, Mead, Ward & Hunt, Consulting Engineers.

The site of the Treatment Plant at Camp McCoy involved the problem of locating the plant away from the barracks, on the downwind side, near the river and at a point sloping away from the barracks. The result was that the plant was located at the southwest corner of the camp and 2,500 feet from the barracks, on the LaCrosse River.

A converted low rate trickling filter plant was decided on so that a high degree of treatment could be accomplished.

Economy in construction and operation was considered, and available materials for speed in construction, as a time limitation was involved. Dependability of treatment, equipment, loading and personnel were also factors.

The system of the collecting sewers involved considerable study, the ground being sandy and rolling. The system is of the gravity type, designed to flow full at the rate of 2 ft. per sec. Sewers are of dual construction in the Company streets, eliminating the tearing up of the entire street for the connections built of vitrified pipe and poured joints. Where the sewers are exposed, they are of metal pipe and insulated for protection.

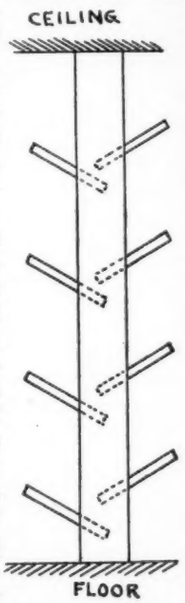
The plant design is for a maximum load of 210 gals. per capita per day of domestic sewage, while the load as designated is 70 gals. per capita per day.

Due to the sandy terrain, a grit chamber, hand cleaned, was designed. A comminutor was placed for operation with a by-pass and hand raked bar screen. The following construction of chambers and equipment completed the treatment plant: four settling tanks, detention 2 hours, full load 1 hour, one or all can be used at a time, sludge collectors, automatic overflow at end of settling tanks, sewage to the settling tanks by gravity, pumps lift influent from settling tanks to filters, control chamber at low rate filters, effluent from filters to final settling tanks. Effluent from settling tanks and filters is so arranged that recirculation is possible. Chlorine treatment is arranged for complete disinfection and is manually and automatically controlled. Sludge digestion tanks are designed for 2.8 cu. ft. per capita. Sludge beds built for digested sludge.

The plant was designed for flexibility in operation, future expansion, elimination of considerable critical materials, and treatment of domestic sewage to a degree of purification to meet the conditions.

A Strong Balanced Storage Rack*

It is sometimes dangerous to attach a rack to an ordinary wall and then pile heavy materials on the rack. It is poor practice because a "one-sided" pull is created. Such a load is an "eccentric load," and eccentric loads on columns or walls sometimes end in disaster. If a similar rack could be attached to the other side of the wall and both sides loaded equally and simultaneously there would be no eccentric load and the possibility of collapse would be materially lessened.



Herewith is a sketch of a strong rack that I have used successfully. I piled heavy materials on it—pipe, bars, angles, and lumber, and it never yielded in the least.

To make a rack of this kind, bore holes in sturdy upright timbers at a slight angle as indicated in my sketch. Insert short pieces of pipe or strong pegs to fit nicely in the holes as shown, fasten the vertical timbers both at the top and bottom, and you have a good serviceable rack capable of holding a tremendous load. By placing the "shelves" on both sides and then loading both sides the desired balance is obtained as mentioned above.

*Contributed by W. F. Schaphorst, Newark, N. J.

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Cuts treating costs... Saves chemicals... Increases efficiency

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In the main treating plant of the giant Metropolitan Water District of Southern California—a system capable of delivering a BILLION gallons of water per day across the entire state of California, and one of the largest water treating jobs in the world—the pH control equipment is 100% BECKMAN! In the mammoth treating plant where the water is softened and purified, Beckman Automatic pH Instruments control the pH of the liming process... of the carbonation process... and the pH of the final treated water. This 100% installation is notable tribute to the dependability of Beckman Equipment!

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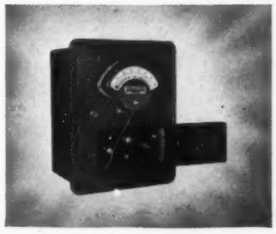
At its Stickney installation—world's largest sewage plant—the Sanitary District of Chicago tried Beckman pH Control on the chemical end of its sewage treating operations ... found that it not only saved time and chemicals, but increased plant efficiency and decreased operating costs so successfully that a second installation was ordered for its Calumet Plant to cut operating costs there. Recently it ordered a THIRD Beckman pH Installation for still another plant in its large municipal system. Clear-cut evidence like that tells its own story!

LARGE OR SMALL, *YOUR* PLANT CAN SAVE WITH BECKMAN pH CONTROL!



The Beckman Automatic pH Indicator—Continuously and automatically *indicates* pH, and operates standard *recording* and *control* equipment for fully automatic pH control. Ask for Bulletin 16!

The Beckman Industrial pH Meter—Ideal for portable plant and field use. Simple, rugged, accurate, and incorporates many unique operating features. Write for Bulletin 211

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Beckman THE LEADING NAME IN pH

Utility FROM STREET TO STREET ...FROM COAST TO COAST!

*ASARCO TUBE-LOY FEATURES

Type K Tube-Loy is a water service pipe which is extruded from a patented lead alloy. This alloy materially improves the physical characteristics of lead, its principal component part, so that the utility of the metal has been considerably extended and increased. *Type K Tube-Loy assures the following advantages:*

- Low initial cost
- Simplified installation
- Greater ductility
- Enduring performance
- Prompt delivery

ASARCO TRADE LEAD PRODUCTS DIVISION MARK PRODUCTS

*GRINNELL SUPERSEAL FEATURES

Grinnell Superseal Flared Tube-Loy Fittings are made from high quality, air furnace malleable iron, expertly galvanized to resist corrosion. *The use of Superseal Type K Tube-Loy fittings assures the following accomplishments:*

- A leak proof joint unaffected by vibration.
- A greater contact area between the tubing and the fitting.
- A design that prevents shearing of Type K Tube-Loy from too great wrench pressure.
- A flare fitting, manufactured from galvanized malleable iron, the most logical material for water service connections.

The complete story of ASARCO Type K Tube-Loy and GRINNELL Superseal Flared Fittings will shortly be available in catalog form, as illustrated. Write to the American Smelting and Refining Company, Lead Products Division, for your free copy.

***Type K Tube-Loy is a product of the AMERICAN SMELTING and REFINING COMPANY, 120 BROADWAY, NEW YORK, N. Y.**
***Superseal Flared Tube-Loy Fittings are produced by the GRINNELL COMPANY, INC., PROVIDENCE, R. I.**

Visit the ASARCO-GRINNELL EXHIBIT

BOOTH NO. 93

62nd ANNUAL CONFERENCE ON WAR TIME WATER WORKS PROBLEMS

JUNE 21st — 25th • CHICAGO

A steam shovel, excavating for new bridge foundations, struck and broke an important main in the water supply of a New York village. The main was buried in the bed of a stream which carried sewage from many village homes. This sewage, washing in and around the break at this low point in the lines, meant a serious threat to public health.

But the waterworks engineer was well prepared to meet such an emergency. His first thought was Per*chlor*on—a quick, dependable means of sanitizing the water supply and safeguarding the health of his fellow townspeople.

Sleeves were applied to the broken main to reduce sewage infiltration and partially restore the water pressure. Taps were made on both sides of the break, and Per*chlor*on was pumped into the main through each tap. Within a few minutes, 3 ppm residual chlorine was detected in nearby domestic water services. This residual was maintained during the five days required to replace the broken pipe.

No B Coli were found in the system as a result of this break. The engineer says, "We give a good deal of credit to Per*chlor*on for our clean record during this emergency."

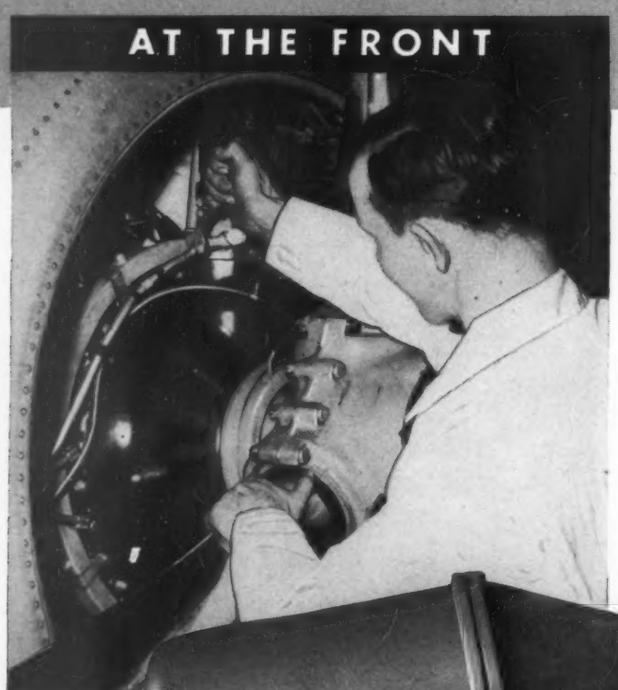
Waterworks engineers in every section of the country have found Per*chlor*on a dependable standby for just such emergencies because of its quick solubility, greater stability and high chlorine content—more than 70% available chlorine. They use it also for sanitizing small water systems, new mains, wells and swimming pools.

At present, Per*chlor*on is, of course, being used to meet urgent war time demands, and we ask our customers to cooperate with us by ordering only for immediate needs, *well in advance* . . . To help you solve some of today's unusual problems, there is a nearby Penn Salt representative who is at your service without obligation. And if you do not have your *free* copy of our illustrated booklet on Per*chlor*on, with valuable data on water purification and sewage treatment, write today to Dept. WS.

Perchloron

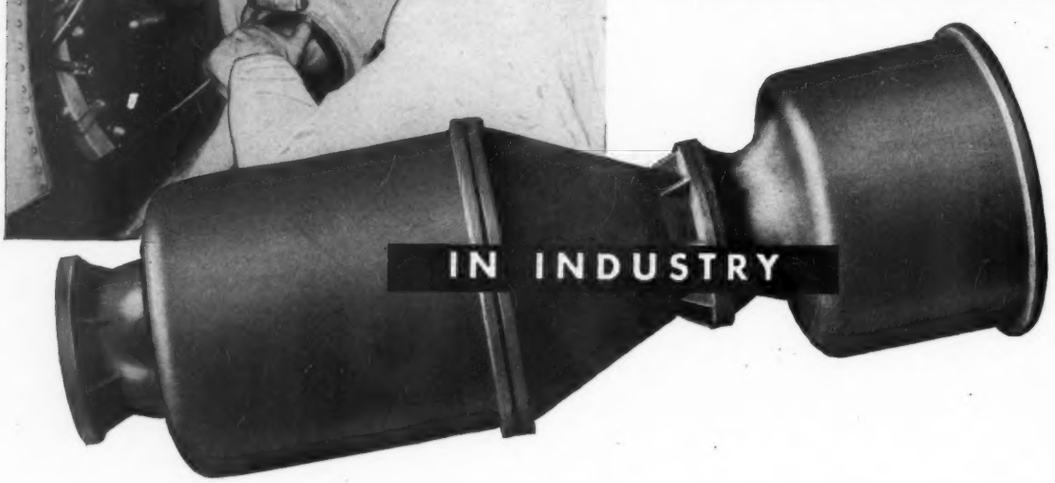
REG. U.S. PAT. OFF.

How *Everdur* helps the war effort...



AT THE FRONT — Because of its exceptional ability to resist vibration, annealed Everdur* 1010 Tubing is being used in fast flying Navy planes for vital fuel lines and high-pressure hydraulic systems. *Registered in U.S. Patent Office.

IN INDUSTRY—In this cast Everdur drum, dilute sulphuric acid from a pickling bath is rinsed from brass components for cartridges . . . Everdur is ideally suited to this corrosive work.



EVERDUR gets the call for these and other tough war tasks for the same basic reasons that made this copper-silicon alloy so useful in sewage treatment plants. It is strong, rustproof and highly resistant to corrosion . . . it has a high endurance limit, fights fatigue . . . it is readily welded and ideally suited to engineering construction involving both wrought and cast parts. These are some of the reasons why Everdur Metal is in such great demand today. 42106

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CONTROL OF ODOROUS AND DESTRUCTIVE GASES IN SEWERS AND TREATMENT PLANTS

Pays Dividends in Public Relations and Preventing Sewer Failures and Damage to Structures and Equipment

By CHAS. C. HOMMON
Supervisor of Sewage Treatment
CANTON, OHIO

THERE are heterogeneous odors from sewers and sewage treatment plants. The so-called sewer gas often referred to in nontechnical language by the layman is not a specific gas. It is an all inclusive term meaning any gas or combination of gases that may be found in a sewer. The most objectionable and far-traveling odorous gases are those originating from stale and septic sewage. Of these volatile compounds, which are expelled from septic sewages, hydrogen sulphide is by far the greatest offender.

This gas, besides creating odor nuisance of intensity and travel distance in proportion to its concentration, has a second and decided objection. It is a dangerously toxic gas in dilution higher than most operators and engineers realize. By authorities it is rated with hydrocyanic acid gas in respect to its toxicity. It is treacherous because individuals working in fatal concentrations lose their sense of smell. Operators working in less than fatal concentrations become accustomed to the odor but in time suffer permanent injuries—notably conjunctivitis and respiratory tract inflammation.

Destructive Effects of Sulphide Gas

In addition to the toxicity, hydrogen sulphide is responsible for costly damages to sewers and plant equipment. Copper parts on expensive switchboards and control panels are in short order sulphided and flake away or crumble to black copper sulphide powder. Short work is made of copper screens and brass work exposed to the moist gas at sewage plants. The first sign is the irridescent blue coloring imparted to copper and its alloys. Hydrogen sulphide can also be easily and simply detected by exposing silver coins for a few hours at points where presence of the sulphide gas may be suspected. The coins turn brown and then black if sulphide gas is present.

Then, one of the most disastrously

The Author

damaging effects from hydrogen sulphide is its hidden attack. This is the acid disintegration of masonry sewers and all metal parts of manhole structures. The sulphide gas in this type of attack is converted by organisms (bacteria) on the walls of sewers into two acids, sulphurous and sulphuric. It hardly need be explained that both of these acids make short work of concrete or mortar. The calcium sulphate produced causes rupture of mortar pipe joints and brick sewers or manholes. It has been known to weaken sewers to the point of complete failure of that part above the sewage flow line, below which no damage is done. Therefore, no full flowing sewer is ever damaged by sulphide gas. This gas is never oxidized by organisms which are present in the liquid but only those which thrive in an atmosphere where there exists some oxygen. If, therefore, it were practical to seal sewers so as to prevent all entry of air, there would be no danger of the so-called gas attack of sewers and manholes.

An Instance

The sanitary outfall sewer extending from the southerly city limits of Canton, Ohio, to the treatment plant offers good evidence as to the destructiveness of sulphide gas.

This sewer is 39 inches in diameter, 6.5 miles in length, and was placed in service in 1915. Type of construction was vitrified segment block, laid up with mortar joints, and has a theoretical carrying capacity of 18 m.g.d. There is one depressed section, 3,200 feet in length, which is constructed of reinforced concrete. This length of sewer is naturally conducive to septic sewage and consequent development of hydrogen-sulphide, especially during the warmer months of the year. The presence of offensive gases was not particularly grievous with the Imhoff contact bed type of sewage plant that was the original companion unit of this outfall sewer. However, in 1925, when the original contact bed units were converted into trickling filters using the conventional spray nozzles that were in general use at the time, the volatile gases made their presence known through the atomizing effect of the spray nozzles. Thus originated a definite odor problem.

An Early Study in Corrective Treatment

In about 1928 through the efforts and assistance of Mr. L. H. Enslow, associated with The Chlorine Institute, some work was undertaken using liquid to control the odors. The Institute furnished the chlorine and the firm of Wallace and Tiernan loaned the necessary chlorine feeding apparatus for the study.

Chlorine was first added to the sewage at a point locally known as the three way manhole, which is the beginning of the main outfall sewer. This station is 6.5 miles above the Treatment Plant and is the point of convergence of three main trunk sewers.

A number of sampling points were established along the sewer for collecting samples for analysis. It was soon learned that the chlorine would do the trick of controlling the hydrogen-sulphide. However, it was difficult to maintain sufficient chlorine and the required dosage was relatively high. The receding area in the depressed section caused an appreciable increase of hydrogen sulphide which, it was believed, defeated the desired results at the plant.

It was obvious that split feeding was the answer; just how many points of desired application were not determined because of the absence of necessary water pressure for operating the chlorine machines at locations below the three-way manhole.

The chlorinators were then moved to the sewage plant and chlorine admitted to the raw sewage just ahead of the bar screens.

This work clearly indicated that a dosage of 10 to 12 p.p.m. would greatly improve conditions at the plant and eventually permanent chlorination equipment was purchased and storage racks for handling ton containers of chlorine was constructed. At this time odor control was the all absorbing question, with only minor consideration given to the need for deterring disintegration of the mortar tile joints and concrete structures.

Attack on these, however, became accelerated in the time intervening and the expensive Canton outfall sewer, weakened by joint attack, has ruptured three times in the past few years. Internal pressures, caused from surcharging, proved too much for the weakened joints. These failures offered good reasons and opportunities for a thorough inspection of the sewer and it was found that practically all of the mortar joints above the normal flow line had disintegrated and ceased to exist. Also many of the liner plates were split off and were found lying on the floor of the sewer. It is assumed that the swelling of the mortar in the joints during the sulphating period created sufficient pressure to pinch off the faces of these tile. In a few instances the velocity of the sewage had caused these fallen plates to gather into sufficient piles to develop major restrictions in the sewer. It was interesting to note that the portion of the sewer below the normal flow line was in a very satisfactory condition, no plates missing and all joints normal, whereas the upper areas showed serious attacks. This same condition prevailed in the approaches to the concrete depressed section. Wherever the concrete mortar was submerged it was in a satisfactory condition, but above the normal flow line (those areas normally in contact with moisture and the gases) serious deterioration was evident.

One of the Early Up-Sewer Chlorinating Stations for Odor Control and Sewer Protection—San Bernardino, Calif.

This picture reveals the small space required for such a station and the method of transfer of the one-ton chlorine cylinder from truck to the in-use pit alongside the chlorinator house. Incidentally this picture was taken just after California's worst floods had half-buried the chlorinator house in deposited silt. With the treatment plant put completely out of commission, this station performed an emergency service of disinfection of the bypassed sewage during the restoration by merely boosting the chlorine dosage.

A great deal more is known today about sewage treatment and the handling of sewage than was available when the Canton outfall sewer was constructed and the writer is frank in admitting that he did not fully appreciate what had occurred or what was occurring in the sewer at the time this investigational work was being done. As a matter of fact, there was little if any evidence in 1928 to show that the attack was proceeding at a serious pace, and chlorination at the plant proper seemed adequate for the odor problem.

Methods of Preventing Sulphide Production

Hydrogen sulphide develops only after all other sources of available oxygen utilizable by bacteria have been exhausted. After this, the oxygen hunger of several species of bacteria is satisfied from the only source left—the sulphates. In taking away the oxygen, the residue is sulphide, which hydrolizes into hydrogen sulphide.

Having laid down this premise, it becomes apparent that there are two general methods of preventing or checking sulphate breakdown. These are:

(1) Introducing more oxygen in the form of air, dilution water containing oxygen, or an oxygen containing compound such as nitrate.

(2) Suppression of bacterial activity and multiplication of organisms which deplete the oxygen and eventually break down the sulphates for their oxygen content.

The sewage operator may employ the following corrective methods:

(1) Air blowing to sweep out most of the volatile (free) hydrogen sulphide and discharge of the air-sulphide exhaust through a tall stack. Or absorption of the sulphide in the exhaust may be attained by passing it through an absorption tower.

(2) Destruction of the sulphide in the sewage by addition of chlorine, which precipitates the sulphur *in situ* and deodorizes in so doing.

(3) The fixation of the sulphide by adding a metallic salt such as copper or iron.

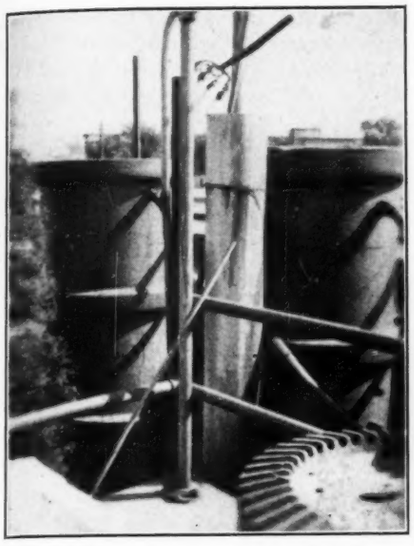
These several methods will now be discussed separately.

(1) Oxygen Introduction

Air blowing in the sewer sounds attractive but has many drawbacks of a practical nature. The scheme has never been successfully developed because of structural and op-

erating expense. The effect secured with flash aeration has short duration, as all activated-sludge plant operators will attest. As a matter of fact, a small air input is worse than none in the overall result, since bacterial multiplication is given impetus and oxygen supply is too limited.

The addition of nitrates (Chilean Saltpeter) has been used; is effective



The Original Contact Towers for the Scott-Darcey Process of Making Ferrous and Ferric Chloride at Oklahoma City.

Discharge from chlorinators passes upwards through iron scrap, producing ferrous chloride.

but surprisingly costly in terms of oxygen units provided.

Dilution, by introducing reasonably clean stream water up-sewer, has been utilized with excellent results during hot dry-weather flow when the practice is most needed, and fortunately is permissible at such times without surcharging sewers or imposing excessive flows on treatment works. Fortunate is the plant manager who can divert a portion of a stream into his sewer system when most needed to maintain clean sewers, dilute and freshen sewage delivered to the plant at much younger age, and prevent degradation and odor production in the system.

(2) Suppression of Bacterial Activity

In winter, lower temperatures of sewage is the natural suppressor of bio-activity. If it were practical to chill sewage to maintain temperatures of not in excess of 70° F. during its travel through the system there would be no odor or sewer attack problem.

The practical alternative is that of partial disinfection of sewage to reduce the total numbers of organisms, suppress their development, and most important of all, to reduce the biological "turnover." What is meant by "turnover" is the number of new generations of young and vigorous organisms per hour. Like all living things, it is the active youth generation who burn up the oxygen in the vigor of living, and not the grandfather generation. Total numbers of organisms may mean little if anything in sewage. What really counts is the age, activity and species of bacteria. This means much in rate of oxygen utilization and depletion, consequently, the speed of reaching the point of sulphide production and its consequences.

To suppress bacterial "turnover" and rates of oxygen depletion, such as is provided by nature in winter operation, is the basis on which partial disinfection of sewage as close to its point of origin as practical, has met with success. Some remarkable results have thus been obtained with up-sewer chlorination at rates of dosage dictated by the temperature-time factor. In some instances (cooler sewage and short period of travel to the plant) as little as 2 p.p.m. of chlorine has been ample. In other instances (drought and high temperatures with long travel periods to the plant) as much as 12 p.p.m. has been required. In others, a two-point application, between the collecting system and the plant, has been required for higher efficiency and chlorine economy. Taking it by and large, the 5 p.p.m. dosage has been effective when applied sufficiently early—i.e., before bacterial "turnover" has gotten a head-start.

During the past several years "preventative chlorination" has been the most popular odor control measure. No set rule can be given for the dosage needed, for reasons above cited. Nor can a universal specification be written concerning the point (or points) of chlorine introduction up-sewer. Therefore, in cases where doubt exists, a hydrogen sulphide and chlorine-demand survey to determine the most effective application point (or points) is the recommended procedure. As a matter of fact, a portable chlorinator may be employed to determine the permanent location (or locations) for maximum chlorine economy.

In connection with such surveys and chlorination point selection, securing assistance of experienced engineers with The Chlorine Institute, 50 E. 41st St., New York City, or the technical service staff of Wallace & Tiernan Co., and/or of the larger chlorine producers, is suggested.

Other Corrective Methods

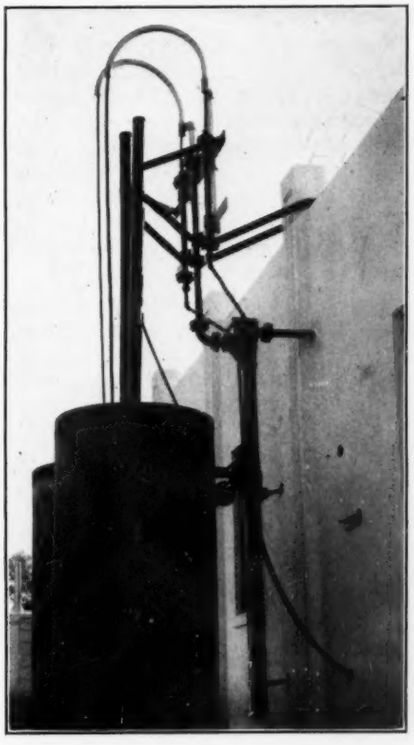
In cases where it has not proved practicable to adopt preventative measures, the following corrective methods are available.

(1) Air Blowing at Plant

So far as we are aware, this method has only been utilized at one plant —Dallas, Texas. In a closed chamber the sewage arriving at the treatment works is air-blown for 4 minutes and in the second pass is blown for an additional 4 minutes with air carrying chlorine gas. The exhaust from the aerating and aero-chlorination chamber is discharged through a stack. The plant is also equipped to employ ordinary chlorination or the addition of an iron salt, which will destroy or "fix" the volatile sulphides, as later explained.

(2) Chlorination

By far the greatest number of plants have been equipped for corrective chlorination at the plant proper, when and if odors become a problem. Particularly has this method been mostly adopted for the smaller plants



Contact Towers for the Scott-Darcey Process at a Small Treatment Plant in Arizona.

In this instance the chlorinated iron produced is employed for chemical precipitation as well as odor control.

and those where odor nuisance is a possibility rather than a probability.

In this method, chlorine is applied just ahead of the bar-screens or in the pump well. The dosage varies considerably, running from 2 to 20 p.p.m. of chlorine. In the majority of such cases, the 10 p.p.m. dosage covers the requirement. The practice of pre-chlorination for the dual purpose of disinfection and odor control simultaneously has gained considerable favor in recent times, the largest plants to adopt this method being those of Buffalo, N. Y., and Detroit, Mich., where pre-chlorination has also proved more economical than post-chlorination, and also more effective as a disinfection measure alone.

In the plant chlorination method the sulphide is destroyed by breaking into the compound and precipitating the sulphur thus

$$H_2S + Cl_2 = 2HCl + S$$

(3) Sulphide Fixation

When adding chlorine *solely* for the purpose of sulphide destruction (i.e., after the sulphide has been produced), the scheme is less effective than the following.

Copper or iron salts may be employed for the purpose of converting volatile sulphide into "fixed" copper or iron sulphide. Since copper is the more costly metal, and since iron chloride can be produced relatively simply and inexpensively on the site of application, this scheme has in recent times become a very popular, effective and inexpensive method.

The iron chloride is produced from scrap iron and chlorine by passing the discharge of a chlorinator upwards through a tank or tower containing the iron scrap. The overflow from the tower is ferrous chloride ($FeCl_2$). The process introduced in Oklahoma City by L. H. Scott, Supt. of Water and Sewage Treatment, and H. J. Darcey, Chief Engr., Oklahoma State Dept. of Health, and known as the Scott-Darcey Process, was taken over and perfected by Wallace & Tiernan Co. In the West and Southwest the method has been rather extensively and effectively used. With the equipment, either iron chlorine or chlorine may be used at will. The equipment can also be operated to produce ferric chloride ($FeCl_3$) for coagulation or sludge filtration at will. Therefore, it has a decided interest because of its flexibility in respect to producing the proper material for the job to be done.

In the matter of odor correction, the use of chlorinated iron has many advantages over direct chlorination. For instance, there are stale sewages which when chlorinated partially develop a decidedly medicated (iodoformish) odors. This odor is not of a traveling nature but is not pleasant and visitors would object to it. On the other hand, chlorinated iron produces absolutely no odor. For a given amount of chlorine, use of the Scott-Darcey method insures 100 per cent efficiency in respect to theoretical hydrogen sulphide removal per pound of chlorine. The explanation lies in the fact that the iron has affinity only for the sulphide and fixes it completely without organic matter interference, while chlorine is always in part used up by organic matter before it strikes the sulphide. Frequently 50 per cent of the chlorine applied is thus used up and only 50 per cent ever reaches the sulphide.

A fact of considerable interest also is that the iron application can be made at any point desired. If, for instance, it is desirable to add it at the beginning of a long sewer, the iron is used up only as hydrogen sulphide is produced. Therefore, the surplus of iron travels along in contact with the sewage or industrial waste without being depreciated in any degree by the organic content. Thus, the iron becomes available as needed during progress of the sewage between the point of application and the plant. It is plain, therefore, that the chlorinated iron method is a measure of correction which involves the utilization of chlorine to its highest advantage. The method insures an efficiency of hydrogen sulphide removal at essentially 100 per cent of the theoretical, this being the destruction of 1 p.p.m. of H_2S for each 2 p.p.m. of chlorine applied, according to the following reaction:

$$H_2S + Cl_2 = 2HCl + S$$

The reactions involved in the chlorinated iron method are:

(1) $Fe + Cl_2 = FeCl_2$

(2) $H_2S + FeCl_2 = 2HCl + FeS$

Since two parts of chlorine by weight accounts for one sulphur, the iron involved can be pictured as a chlorine carrier in the process of "indirect chlorination."

From the above, it is readily observed that the more modern use of chlorine as an agent of controlling hydrogen sulphide would have been of material benefit in preventing failure of Canton's 26 year old outfall sewer, as well as correcting the odor problem at the plant proper. When considering the cost of a large outfall of material length it is apparent that considerable can be spent for Summer time chlorination as a measure for extending the life of such a structure to that of normal expectancy.

The Triple Purpose Chlorinator Installation at Dallas, Texas

The 1,000-lb. capacity dry feed machine at center is used for "Aero-Chlorination" in grease separation and/or deodorization of stack gas. The two 2,000-lb. capacity solution machines are used for prechlorination odor control or producing chlorinated copperas at will.

Sanitary Engineering Division of A.S.C.E.

Schedules Sessions for St. Paul-Minneapolis Meeting

The Sanitary Engineering Division of the Am. Soc. of Civil Engineers will hold a forenoon session in St. Paul, Minn., in conjunction with the Summer Meeting of the Society, to be held at the University of Minnesota, July 22-24.

The Sanitary Division Session will be held on the forenoon of Thursday, the 23rd. In the afternoon an inspection trip to the Minneapolis-St. Paul Sewage Treatment Plant is being arranged by Geo. J. Schroepfer, who has developed the Division's program, which follows:

Sanitary Engineering Division Sessions

Thursday, July 23, 1942

(Linn H. Enslow, Chairman, Executive Committee, presiding)

Forenoon Session

"Operation of Army Sewage Plants"—L. H. Kessler, Chief, and John T. Norgaard, Assoc. San. Engr., Water, Sewer and Services Unit, Repairs and Utilities Branch, Construction Division of the War Department, Washington, D. C.

Discussion.

"Experiences in the Operation of the Twin Cities Softening Plants"—(a) Minneapolis Plant. A. E. Jensen, Supt. of Water, Minneapolis. (b) St. Paul Plant. L. M. Thompson, Supt. of Water, St. Paul.

Discussion by Melvin P. Hatcher, Chief Engr. and Supt., Water Dept., Kansas City, Mo.; Charles H. Spaulding, Supervising Chemist, Department of Water, Springfield, Ill.

General discussion.

"Utilities Preparedness Program of the City of Chicago"—(a) Sewer Repairs. Thomas Garry, Supt. of Sewers, Dept. of Public Works, Chicago. (b) Simulated Emergency Repair of Large Water Mains. B. W. Cullen, Supt. of Water Pipe Extensions, Dept. of Public Works, Chicago.

Discussion.

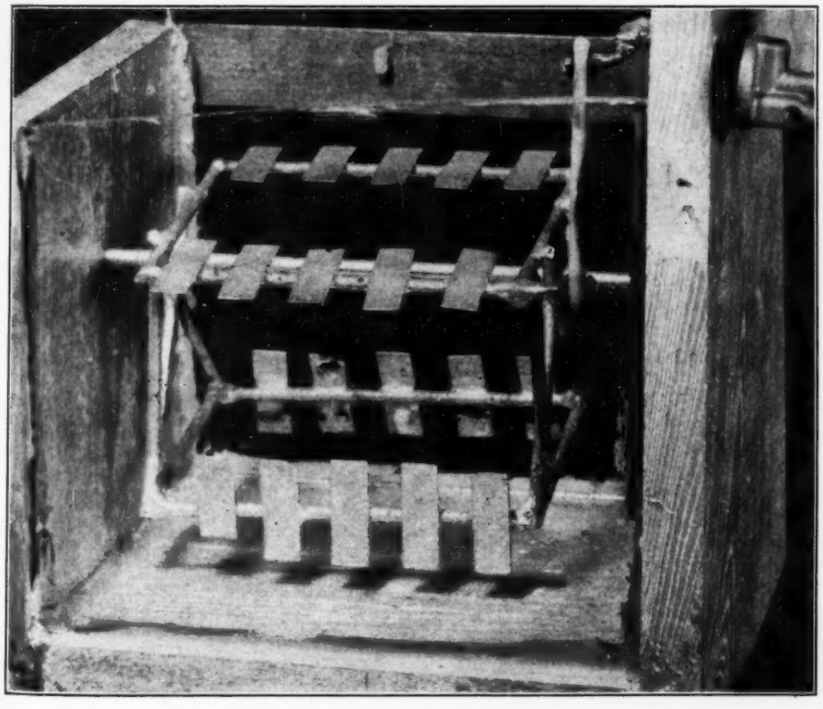
Luncheon

Afternoon Session

Brief Description of Operaton of Minneapolis-St. Paul Sewage Treatment Plant by George J. Schroepfer, Chief Engr. and Supt., followed by plant inspection.

THE CASH MIXER

Having heard of the mechanical mixer conceived and built by Bartley J. Cash, Sup't. of Water Works at Newman, Ga., a photograph and description of it was requested of the inventor.



This mixing unit for coagulating water was constructed by Mr. Cash while superintendent of the water plant of Cornelia, Ga. The accompanying picture is that of the model built in perfecting the machine.

The paddles do not revolve but are merely oscillated back and forth. This motion is secured through a pitman rod attached to a crank arm on the speed reducer shaft. The agitator is mounted eccentrically on its shaft in a manner to preclude stopping of the swinging agitator on dead center. The degree of mixing is secured by speed changes and/or the distance of swing of the paddles away from the vertical.

In operation the oscillating paddles impart to the water a rolling motion which is an excellent floc building motion. Mr. Cash reports that the mixer saved considerable in coagulating chemicals as well as providing dependable coagulation.

The Cash mixing machine is described in considerable detail in the patent granted the inventor January 21, 1941, which carries the number 2,229,238.

CONTENTS OF HORIZONTAL CYLINDERS

A Multiple Use Chart for Vertical as Well as Horizontal Tanks, Pipe Lines, Etc.

By J. TARRANT
Assoc. M.Inst.C.E., A.M.I.Mech.E.
RUISLIP (MIDDLESEX), ENGLAND

THE alignment chart printed herewith gives a convenient method of finding the contents of cylindrical tanks placed with the axis horizontal for all depths of liquid in the tank.

It is usually the case that only a fair approximation of the tank contents is required, and the calculation by exact formula is not very readily done.

Formulas for horizontal cylindrical tanks contents are generally printed in two forms, one for use when the liquid level is above the centre and the other when the level is below the centre of the tank.

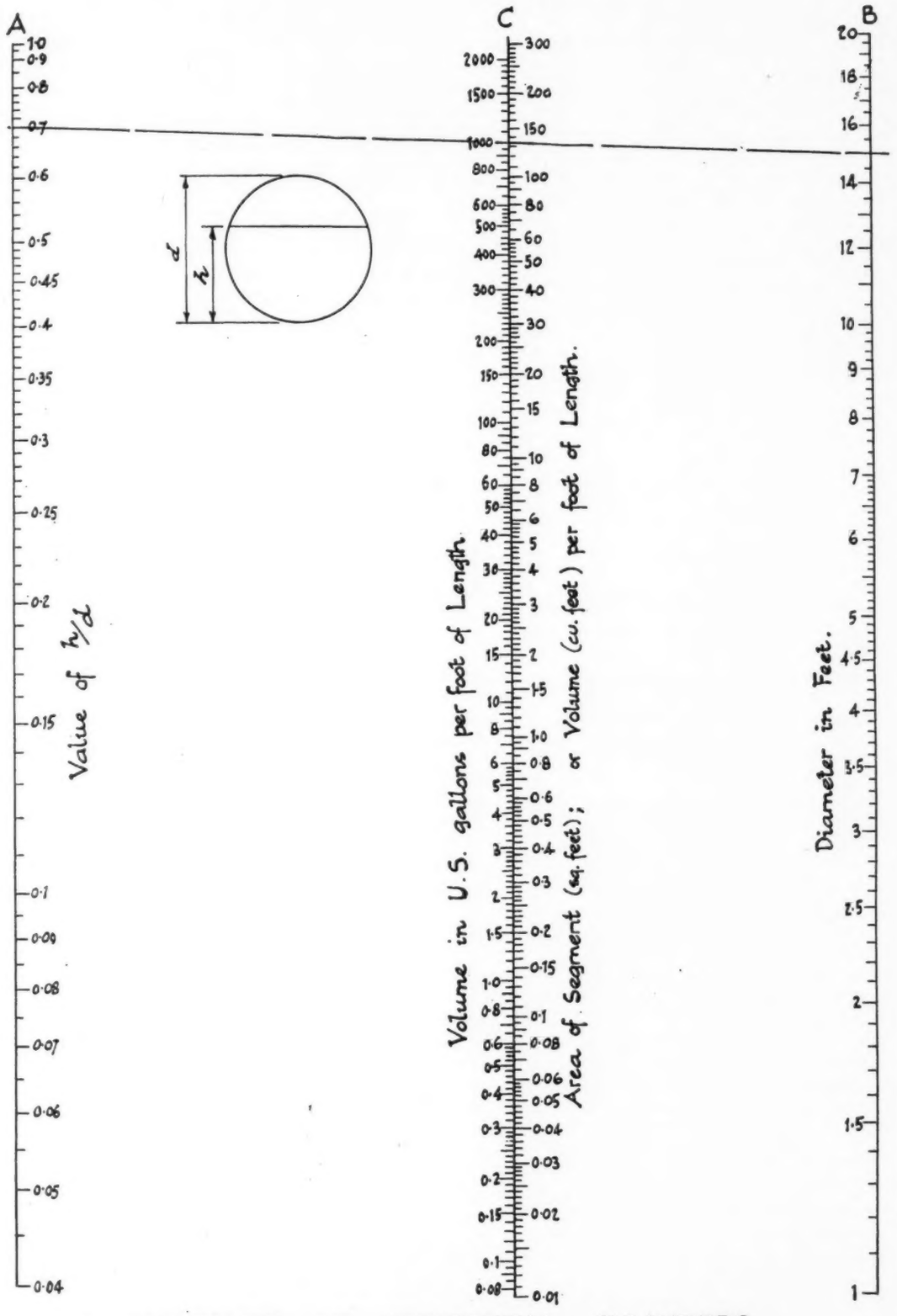
On the chart, the scale relating to the depth of liquid is continuous; that is to say, it applies whether the liquid level be in the upper or lower half of the section.

To use the chart, a straightedge is placed across the scales, and the intersections on the three scales give the related values. Line A gives the ratio of depth of liquid to the diameter of the tank; line B, the diameter of the tank in feet; and line C, the contents, in cubic feet and gallons, for each foot of length of the tank. In the example shown by the line across the chart, a tank 15 feet in diameter in which the contents are 10 feet 6 inches deep, will contain approximately 1,000 gallons per foot of length.

By using the fixed value of $h/d = I$, the chart also gives contents per foot of height of a cylinder with vertical axis, and also the contents of full pipes per foot of length.

Sometimes the dimensions of a tank or pipe line will not be in feet, but the chart may still be used. The contents will be in units which correspond to the dimensional units, and the scale of gallons will not apply. For example, if the diameter is taken in inches, the contents, *read on the cubic feet scale*, will be in *cubic inches* per *inch* of length.

The calculation of contents is clearly based on the area of the segment of a circle, which is what the contents scale on line C shows, and the calculation of segmental areas, in any dimensional units, may be made by use of the chart so long as the cubic feet scale is read, and units ascribed to this which correspond to the units used for the diameter. When the diameter is in feet, the area of the segment is in square feet; for meters, the area is in square meters; for inches, in square inches, and so on.



CONTENTS OF HORIZONTAL CYLINDERS.

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The Editor's Comments

"Old Glory"—Keep It Flying!

LAST month it was felt that we had nothing sufficiently worthy for this page that had not been said elsewhere in the issue, to justify use of the space or the reader's time to read it. This leads us to wonder how many readers have noticed that in other issues also we have felt the same way about use of the space and the taking of reader's time for no reason other than an assumption that an editorial is something of a "must" for every issue. In other words, our last month's issue was not the first to be sent to press without a "message" of some sort from an inspired editorial pen. Fact is, Ye Ed. has experienced more perspiration than inspiration in getting out some issues, and some of his writings may have reflected something of the sort. This month is different though and we hope that this page will be read by many who will find the time.

In choosing the cover picture for this number, which is to issue at the approach of the anniversary of America's independence and the birth of our "American Way of Life," we felt inspired. Also in the matter of something to say on this page we feel inspired on several counts.

First, we have felt inspired because of the account which the defenders of "Old Glory" have given of themselves on Bataan peninsula, at Corregidor, and more recently on the Pacific and over the Mediterranean. We have also experienced a marked inspiration, as did thousands of others who felt the pulse of that Flag Day celebration in Chicago on last Sunday, June 14th, and saw some of the spirit of that gigantic parade which, after a long day of putting together some of this voluminous number (a product of "perspiration"), we found still going at 1:30 on Monday morning. In addition to the military showing, this was the "People's Parade," which left one with a pretty good idea as to why the "American Way" is obliged to continue and why true Americans just can't be whipped after they have made up their minds that there is fighting to be done.

And, we felt still further inspired to write in this vein as the result of the re-reading of Naseb Damoose's inspiring story of "What Democracy Means to Me" in our May issue, wherein he relates some of the history of his ancient American family, of his parents' migration to this land of privilege, and his comparison of the sparse opportunities available to the common man in other countries as contrasted to the "American Way" here which permitted this immigrant boy to receive an education and climb the ladder which has taken him from a laboratory helper in the Grand Rapids Sewage Plant to plant superintendent in a neighboring community and now to the position of Director of Public Services at Battle Creek, Mich. A No. 1 citizen, Naseb Damoose had the community spirit which caused his Rotarian brothers to draft him as a substitute for a non-appearing out-of-town speaker one day. With no opportunity for preparation, he spoke from the heart of a grateful American who, but for his father's decision to come to this land, might never have known "What Democracy Means to Me." His talk went over with a bang.

We wondered what the reactions of our readers would be to this type of article in a technical magazine, and we have now found out. The splendid commentaries which we have received from readers commending us for printing Mr. Damoose's article is a great satisfaction. One in particular we would like to quote. It comes from a one time Dutch immigrant who has risen high in his chosen field. Here it is: "The printing of the Damoose article needs no apology. It is a privilege to publish and to read. Most of us in a similar position, as was the author originally, are at a loss for words to express the thoughts as well."—Rudolf.

Do Your Bit—Turn in the Scrap

AS CHAPTER TWO of "Old Glory—Keep It Flying" we wish to remind water works and sewerage men that there was never a time like the present to make a good house-cleaning of utility and public service properties count for as much.

Our experience has been that the quantity of non-serviceable metal here and there around water works and power plants is astonishingly impressive if it is ever pulled out from here and there and placed in one pile. In reorganization or exchange in ownership of water utility properties we have known cases where a survey followed by salvage has not only markedly improved plant appearances and maintenance and operating efficiencies, but has actually yielded unthought of impressive returns in the coin of the realm.

In the present need for every pound of available scrap metal and non-expendible metal equipment, in the production of armaments and war material, what the return from salvage may mean in monetary values is relatively unimportant—the thing that counts is the return of these needed metals to circulation and the doom of Hitler's gang and the despicable Japs.

Every scrap of brass, bronze and copper will help stop another Jap and every ounce of old rubber boots, hose, tires, etc., will do a lot in the aggregate toward winning this war, which should be considered as the No. 1 MUST on every American's list. When you consider your own plant alone, the amount of junk materials to be gathered together may not amount to a great deal, *but*, multiply your contribution by the thousands of American plants and you will see what your "bit" will add.

From this writer's experience it will surprise many to see what the salvage pile will look like when once this clearing out process gets under way. Pulling out one dead pipe line will uncover others. A search behind the old boiler may bring forth a couple of old forgotten chlorine cylinders; and pip galleries of old filter plants can yield an important poundage of unrequired metal. We have known old standpipes that could well be turned into modern tanks of another variety. There are many forgotten mains and service lines—some that may be found responsible for much unaccounted for water waste.

All in all, we can visualize a real mountain of metal scrap to be had if every water works operator made up his mind that a *real* house-cleaning and salvage program constituted a war service counting for many times its effectiveness if done "today" rather than "tomorrow." We would like to have for our Honor Roll the names of all managers who can report that they have a salvage program either under way or completed.

L. H. Enslow

FOR PERFORMANCE USE Economy SEWAGE PUMPS

Economy builds a complete line of Sewage Pumps. Economy equipment will do your job well. Write for your copy of Economy's latest data book, crammed full of engineering data. Sent free upon request.

Vertical Direct Connected Pumps with self contained motor mountings used in shallow settings.

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100 to 8,000 GPM

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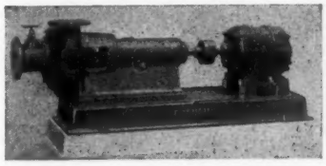

Horizontal Solid Shell Pumps with suction and case cleanouts. Also available in split shell type.

Capacities
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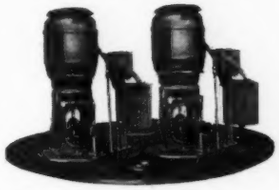

Duplex Submerged Type Sewage Pumps. For either general or non-clog service.

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Vertical Pumps for Open Shaft Drive. Combination Supporting Base and Elbow with quick acting suction and case cleanouts.

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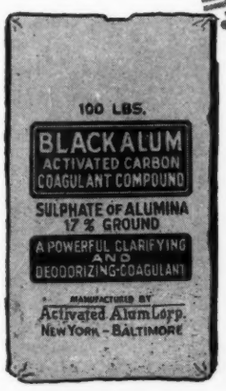

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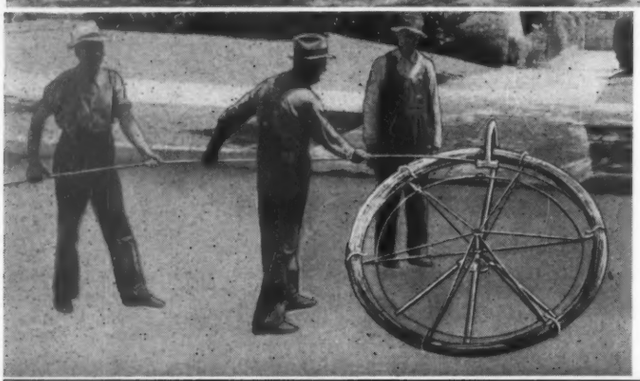

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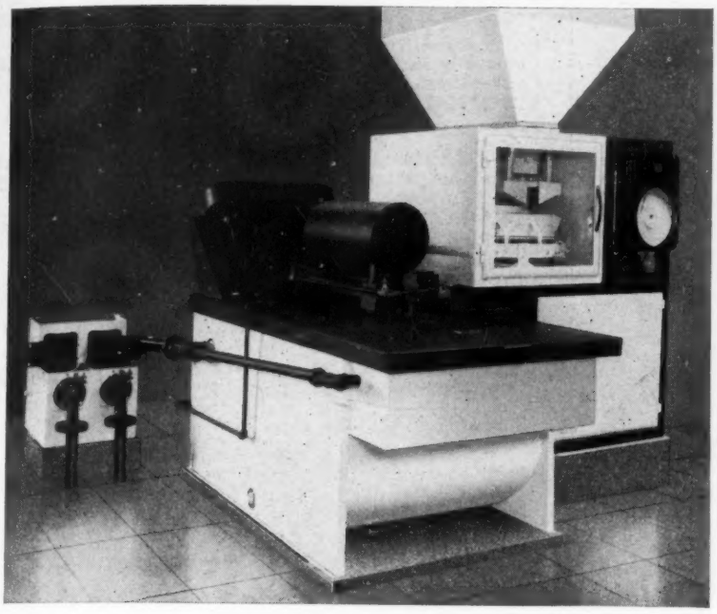

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Omega lime slaker with gravimetric feeder. The belt type gravimetric feeder is equipped with a chart type operation recorder for keeping a permanent record of the feeder performance. The insulated slaker has built in heat recovery coils for efficient, high temperature slaking. The division box at the left proportions the slaked lime to two points of application. This is accomplished by means of OMEGA Adjustable Proportioning weir valves

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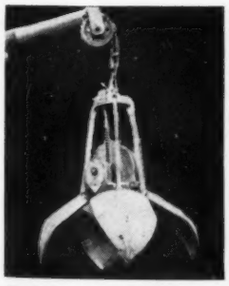
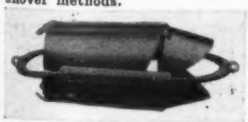
Now! . . . A new combination of equipment that cleans BOTH Catch Basins and Sewers—quickly. Make sewer and catch-basin cleaning routine operations and maintain your sewerage system at 100% operating capacity.



FOR CATCH BASINS. Orange Peel bucket operates through man-hole opening. A tremendous time-saver over old hand-shovel methods.



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Tree roots, sand, gravel, and other heavy debris decrease and eventually stop sewage flow. Damage from this clogging can be avoided by a small precautionary investment—averaging only 3½c to 7c per foot—in the seasonal renovation of your sewage system. These low costs are possible only with this easily interchangeable equipment—powered by the OK Champion Twin or Single Rig Power Cleaner. **Write for Free Literature.**

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① MAXIMUM FLOC formation! That's what you get with Rex Slo-Mixers, because they provide just the right turbulence. By decreasing the turbulence progressively as floc size increases, the maximum floc size is preserved until the settling basin is reached!

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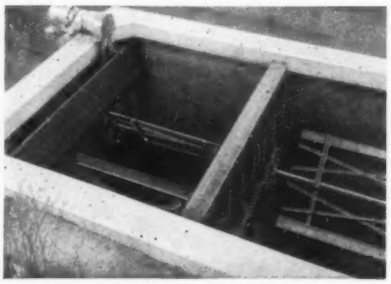

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REX SLO-MIXERS

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MEETINGS SCHEDULED

June 18-19—MINNEAPOLIS, MINN. (Nicollet Hotel)
Central States Sewage Works Association. (15th Annual Convention.) Sec'y-Treas., E. J. Beatty, 458 State Office Bldg., Madison, Wis.

(Note the change in schedule of this meeting from October in the past to June henceforth. This year the dates were purposely chosen to immediately precede the A.W.W.A. Convention, which is to be held in Chicago, June 21-25, with a day for fishing in between.)

June 21-25—CHICAGO, ILL. (Stevens Hotel)
American Water Works Association. (Conference on Wartime Water Works Problems.) Executive-Secretary, Harry E. Jordan, 22 East 40th St., New York, N. Y.

July 22-25—MINNEAPOLIS, MINN. (University of Minnesota)
American Society of Civil Engineers. Secretary, Geo. T. Seabury, 33 West 39th St., New York, N. Y.

(See Program Page 281)

Aug. 12—CAMDEN, ME.
Maine Water Utilities Association. Secretary, Earl A. Tarr, Winthrop, Me. (Next meeting Oct. 14th, Fryeburg, Me.)

Aug. 25-28—HOUSTON, TEXAS
American Society Sanitary Engineers. Secretary, J. W. Walker, City Hall, Waterbury, Conn.

Aug. 25-26—HARRISBURG, PA. (Penn-Harris Hotel)
Pennsylvania Sewage Works Operators' Ass'n. (Annual Meeting.) Sec'y, Bernard S. Bush, State Dept. Health, Harrisburg, Pa.

Aug. 27—HARRISBURG, PA. (Penn-Harris Hotel)
Pennsylvania Water Works Operators' Ass'n. (Annual Meeting.) Sec'y, I. M. Glace, 22 South 22nd St., Harrisburg, Pa.

Sept. 9-11—TRAVERSE CITY, MICH. (Park Place Hotel)
Michigan Section, A.W.W.A. Sec'y, M. N. Gerardy, Sup't Water Supply, Water Board Bldg., Detroit, Mich.

(Meeting jointly with)

Michigan Conference on Water Purification. Sec'y, R. J. Faust, Dep't of Health, Lansing, Mich.

Sept. 15-18—POLAND SPRING, ME. (Poland Spring House)
New England Water Works Association. Sec'y, Frank J. Gifford, 613 Statler Bldg., Boston, Mass.

Sept. 17-18—CHEYENNE, WYOMING (Frontier Hotel)
Rocky Mountain Section A.W.W.A. Secretary, B. V. Howe, 201 Argonaut Hotel, Denver, Colo.

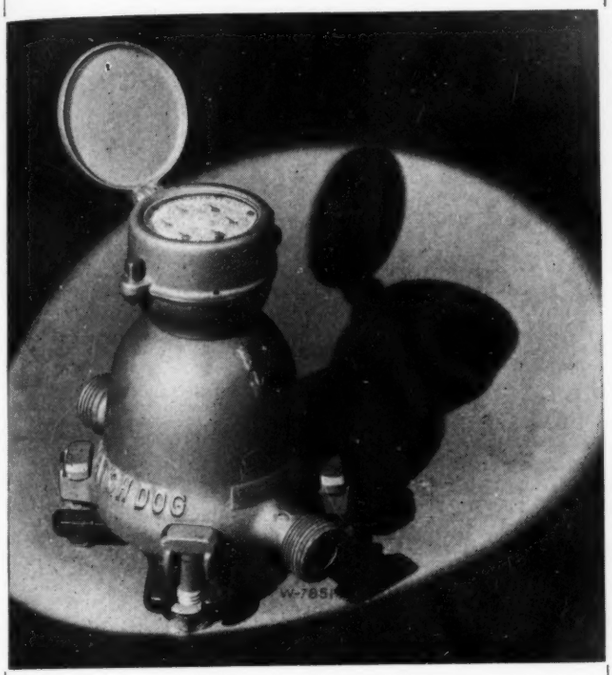
Sept. 18—PITTSBURGH, PA. (Roosevelt Hotel)
Western Pennsylvania Section A.W.W.A. Secretary, E. P. Johnson, 418 Flannery Bldg., Sta. 13, Pittsburgh, Pa.

Sept. 24-26—ST. PAUL, MINN. (Lowry Hotel)
Minnesota Section A.W.W.A. Secretary, A. M. Finch, Wallace & Tiernan, Inc., 416 Flour Exchange, Minneapolis, Minn.

(Continued on Page 118)

The FIRST

Water Meter patent in the United States was granted to Henry R. Worthington in 1855



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most ferrous pipe must be **COATED** TO RESIST CORROSION

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LEMIEUX ISLAND FILTRATION PLANT.....Ottawa, Ontario
MAHONING VALLEY SANITARY DISTRICT.....Niles, Ohio
MUNICIPAL WATER PLANT.....Columbus, Ohio
MUNICIPAL WATER PLANT.....Peru, Ill.
U. S. GOVERNMENT FILTRATION PLANT..Ft. Leavenworth, Kans.
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BACHMAN WATER PURIFICATION PLANT.....Dallas, Texas
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MUNICIPAL WATER PLANT.....Covington, Ky.
MUNICIPAL WATER PLANT.....Ann Arbor, Mich.
CLAYTON SEWAGE DISPOSAL PLANT.....Atlanta, Ga.
SEWAGE DISPOSAL PLANT (2 installations).....Cleveland, Ohio
MUNICIPAL WATER PLANT.....Benton Harbor, Mich.
MUNICIPAL WATER PLANT.....Warren, Ohio
MUNICIPAL SEWAGE DISPOSAL PLANT.....Detroit, Mich.
MUNICIPAL WATER PLANT.....Flint, Mich.
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WATER FILTRATION PLANT.....Ottawa, Kansas
EL RENO WATER TREATMENT PLANT.....El Reno, Oklahoma
CITY OF GRAND FORKS.....Grand Forks, North Dakota
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MEETINGS SCHEDULED

Sept. 25—NEW LONDON, CONN. (Ocean Beach Pavilion)
New England Sewage Works Association. (Fall Meeting.) Sec'y-Treas., LeRoy W. VanKleeck, State. Dept. of Health, Hartford, Conn.

Oct. 7-9—PHILADELPHIA, PA. (Benjamin Franklin Hotel)
Four States Section A.W.W.A. Secretary, H. Lloyd Nelson, 1624 Lincoln-Liberty Bldg., Philadelphia, Pa.

Oct. 12-14—ROCHESTER, N. Y. (Sagamore Hotel)
American Society Mechanical Engineers. Secretary, 29 West 39th Street, New York, N. Y.

Oct. 12-15—LITTLE ROCK, ARK. (Marion Hotel).
Southwestern Section A.W.W.A. Secretary, Lewis A. Quigley, City Water Works, 3320 W. Berry, Fort Worth, Texas.

Oct. 15-17—CLEVELAND, OHIO (Hotel Statler)
Ohio Conference on Sewage Treatment. (Meeting with Federation of Sewage Works Associations). Sec'y-Treas., W. D. Sheets, 568 E. Broad Street, Columbus, Ohio.

Oct. 18-21—CLEVELAND, OHIO (Statler Hotel)
American Public Works Association. (Annual Public Works Congress.) Exec. Dir., Norman Hebden, 1313 East 60th St., Chicago, Ill.

Oct. 19-21—PADUCAH, KY. (Irving Cobb Hotel)
Kentucky-Tennessee Section A.W.W.A. Secretary, H. D. Schmidt, Div. San. Eng., State Dept. of Health, Nashville, Tenn.

Oct. 20-21—WAUSAU, WISC. (Hotel Wausau)
Wisconsin Section, A.W.W.A. Secretary, Leon A. Smith, Sup't of Water Works, City Hall, Madison, Wis.

Oct. 22-24—ST. LOUIS, MO. (Coronado Hotel)
Missouri Valley Section, A.W.W.A. Sec'y, Earle L. Waterman, 104 Engineering Hall, University of Iowa, Iowa City, Ia.

Oct. 22-24—CLEVELAND, OHIO (Hotel Statler)
Federation Sewage Works Associations. (3rd Annual Convention.) Sec'y, H. W. Wisely, Urbana-Champaign Sanitary District, Urbana, Ill.

Oct. 27-30—ST. LOUIS, MO. (Jefferson & Statler Hotels)
American Public Health Association. Exec.-Sec'y, Dr. Reginald M. Atwater, 50 West 50th St., New York, N. Y.

Oct. 28-30—OAKLAND, CALIF. (Hotel Oakland)
California Section, A.W.W.A. Sec'y, H. Arthur Price, Dept. Water and Power, 316 West 2nd St., Los Angeles, Calif.

Oct. 28-31—OAKLAND, CALIF. (Hotel Oakland)
Water and Sewage Manufacturers Association, Inc. Chairman, J. R. Barker, 320 Market St., San Francisco, Calif.

Nov. 2-4—DURHAM, N. C. (Washington Duke Hotel)
North Carolina Section, A.W.W.A. Sec'y, R. S. Phillips, Chief Chemist, Water Department, 206 Dacian Ave., Durham, N. C.

(Meeting jointly with)

North Carolina Sewage Works Ass'n. (22nd Annual Meeting). Sec'y-Treas., R. S. Phillips, 206 Dacian Ave., Durham, N. C.

Nov. 5-6—(Place not decided)
Virginia Section, A.W.W.A. Secretary, F. H. Miller, Ass't Engr., Bureau of Sanitary Engineering, Dept. of Health, Richmond, Va.

Liquid Chlorine AND Soda Ash

••• No. 1 BASIC MATERIALS FOR UNCLE SAM'S ARSENAL!

As a user of liquid chlorine or soda ash, you are probably well acquainted with the fact that these products are, either directly or indirectly, a factor in nearly all industries—*practically every one of which is today on a war time production basis!*

As with war producing industries, the public health services of this country are on a war time basis. The responsibility of these agencies under the *best* of circumstances is always a grave one. Now, in war time, this responsibility is increased a thousand fold.

Precious as liquid chlorine and soda ash are to vital war production, these Solvay products are still available in required amounts to the public health services for water and sewerage treatment. We must all conserve and use them carefully so that every possible pound of these vital materials can be used to the fullest extent for victory!

SOLVAY SALES CORPORATION

Alkalies and Chemical Products Manufactured by The Solvay Process Company

40 RECTOR STREET NEW YORK, N. Y.

BRANCH SALES OFFICES:

Boston • Charlotte • Chicago • Cincinnati
Cleveland • Detroit • New Orleans • New York
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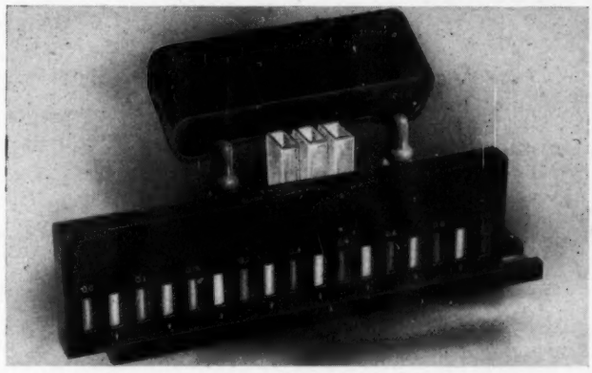
HERE'S *Accurate* pH AND CHLORINE CONTROL



Taylor Slide Comparators, light, compact and molded of durable plastic, use liquid colorimetric standards which assure accurate determinations . . . because comparisons are always made with standards of a similar medium. It takes only two minutes with a Taylor Slide Comparator.

All Taylor Color Standards carry AN UNLIMITED GUARANTEE AGAINST FADING!

Write for illustrated 80-page booklet "Modern pH and Chlorine Control" . . . or see your dealer today!

W. A. TAYLOR AND CO.
7308 YORK RD. • BALTIMORE, MD.

3 *Money, Time and Labor Saving Features of*

UNIVERSAL CAST IRON PIPE

Laid with Only Wrenches →

No Caulking Materials →

No Gaskets. No Bell Holes to Dig. →

For water supply, fire protection systems, sewage disposal systems, industrial, and irrigation. Flexible.

Dept. C
THE CENTRAL FOUNDRY COMPANY
386 FOURTH AVENUE, NEW YORK, N. Y.

Gentlemen: Send us information and catalog on UNIVERSAL CAST IRON PIPE.

NAME .....

STREET .....

CITY .....

LIME.. ALWAYS USEFUL . . . OFTEN INDISPENSABLE

Lime is a very important agent in the treatment of municipal and industrial water supplies. Its use is increasing steadily for water softening; for treatment prior to filtration; for neutralization of acid water; and for the prevention of corrosion, "red water," and scale formation. Lime is easy to use and low in cost.

Its high quality as produced by members of this Association and the convenience of plant locations are added values deserving your recognition and contributing to the solution of your problems.

Rely on LIME *-tested by time*

This Association is an organization of leading lime manufacturers formed to encourage a better appreciation of the economic value of lime in all its uses.

We welcome opportunities to send interested waterworks officials our lime specifications and full impartial data; to put them in touch with our nearest manufacturing member; or to serve in other ways the men responsible for producing better water.

Whatever your water treatment, learn about lime.

NATIONAL LIME ASSOCIATION

927 Fifteenth St., N. W., Washington, D. C.

RUSTOP saves your tanks from costly corrosion

"RUSTOP"

the cathodic system of corrosion prevention, reduces maintenance costs and prolongs the life of your tanks indefinitely.

Entirely automatic; functions in cold or warm weather; protects tank and riser; old or new tanks without special preparation. Let us quote you on stopping rust in *your* tanks.

ELECTRO RUST-PROOFING COMPANY

3rd National Bldg. Dayton, Ohio

Visit Our Booth No. 80 During the A.W.W.A. Convention

for **QUICK REPAIRS** *in* **DEFENSE EMERGENCIES!**

For wartime emergency-breaks in pipe lines, this Doublex Simplex Split Sleeve will enable you to make quick, economical, effective repairs. You should have a supply of several of each different size that you might need. Thousands in use, some for 13 years. Order now from shipping point nearest you as follows: Birmingham, Dallas, Kansas City, Los Angeles, Minneapolis, San Francisco, Pittsburgh.

AMERICAN CAST IRON PIPE CO.

BIRMINGHAM, ALA.

Dallas Houston El Paso Pittsburgh Kansas City
Chicago Minneapolis New York City Cleveland
Los Angeles San Francisco

EQUIPMENT NEWS

Pittsburgh - National Announces the New Empire Victory Meter

• It has become something of a habit for Pittsburgh Meter to announce some new developement at AWWA Convention time. This year it is another departure in meter design—the Empire Victory Water Meter.

The Empire-Victory is designed with iron outer case and a molded glass register box in order to conserve vitally needed brass for the war effort. The manufacturer states that about 70% of the bronze normally used in a domestic size meter has been eliminated, without sacrificing any of the quality construction details that have for 72 years been associated with name "Empire" on water meters.

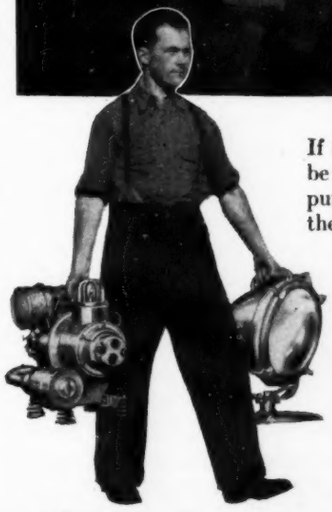
It is stated that the cast iron outer casing of the Victory model is especially treated, coated and lined to prevent the formation of rust. Machined surfaces are chemically treated to inhibit corrosion. The casting surfaces are protected with a coating of "Resistin", which is described as a special synthetic resin enamel finish, permanently bonded to the metal. Lead alloy liners are provided at all points of contact between the measuring chamber and the outer shell.

Of special interest is the molded glass register box. This is a single-piece, strong, molded glass unit which fits snugly over the register and is retained against a fibre gasket by two screws. The manufacturer states that the glass used is thick and strong and that it will withstand considerable abuse. Interestingly, the design permits this glass unit to serve both as a register box and as a lid.

The Victory Meter utilizes the same oscillating piston principle of measurement that has proven so successful in all Empire meters. The measuring chamber is of the snap joint type, within which operates a balanced piston having a centrally located web. The design requires the use of only three interior bronze castings. A four-wheel, oil enclosed gear train is provided—the top half of the measuring chamber acting as the gear train bottom plate.

(Continued Page 122)

Homelite Portable Pumps and Generators are veterans of many emergencies—floods, hurricanes, fires, serious power failures and several others. Wherever emergency floodlighting or instant pumping or quick repairs have been necessary, Homelites have been right on the job. Now these readily portable, self-operating units are ready for a greater emergency — *WAR*. Thousands of water works and public works departments have them on hand ready for any blitz.



A Homelite Generator (above) and a Homelite Pump are easily carried by one man—transportation difficulties are eliminated. Action is insured.

If bombs blow up water mains, Homelite Pumps can be put right on the job. They'll have the craters pumped out in no time so that repair crews can do their work with a minimum of delay. And if it comes at night, Homelite Generators will give men the floodlighting they need for speed. Also for fighting night fires caused by bombings; or for power standby at telephone or signal stations; illuminating hospitals, Red Cross stations, and defense centers, Homelite Generators will be at their posts ready to do their duty.

Homelite Pumps and Generators can take it. Those that have them know they are built to stand up without failure under the most severe operating conditions.

KEEP 'EM FIT FOR THE JOB

A few simple precautions such as keeping spark plugs clean, carbon out of the cylinders, the right mixture of oil in the gasoline, etc. will keep your Homelites in the pink of condition. Send for our service bulletins that show how to get the most out of your units. Specify model and serial numbers of the Homelites you now have.

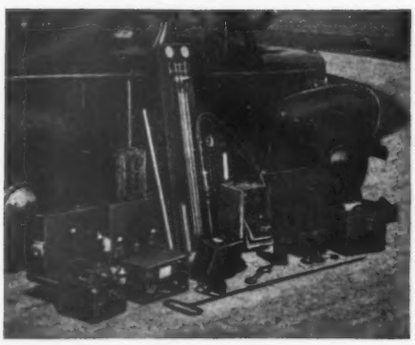
Homelite Corporation

2506 RIVERDALE AVE., PORT CHESTER, N. Y.

THIS NEW

EMERGENCY SERVICE CAR

is now at your COMMAND!



This new emergency car is equipped with all of the latest modern scientific instruments for detecting and locating all of your water distribution problems, such as leaks, lost pipe, valves, tees, crosses, dead ends, abandoned services—will also locate fixtures that are too deep for a dipping needle.

On water leak surveys this car will cover an area of one hundred fire hydrants in one eight hour day, and

Will tell you WHERE TO DIG for leaks, lost pipe, valves, etc.

This emergency car can be hired by the day, week or by contract.

For prices write to

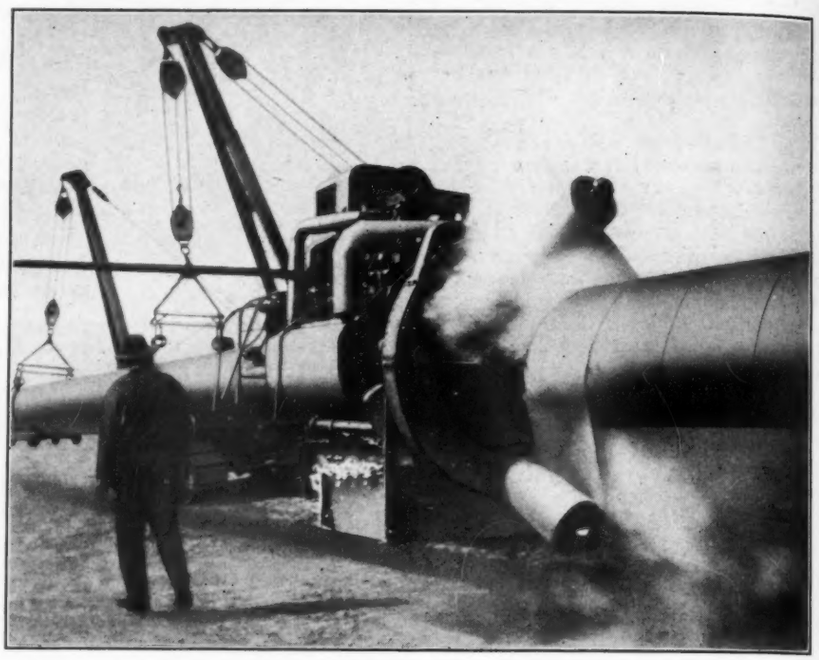
S. F. FERGUSON
DOUGLAS HOTEL BLDG.
NEWARK NEW JERSEY

also
Eastern Distributor for
"UNIVERSAL"
Water Leak Detectors and Pipe Locators

The design is described as eliminating all need for interior screws, and makes possible the assembly of all working parts as a complete unit before installation in the meter case.

A new bulletin describing the Empire Victory Meter has been published and copies may be obtained by writing to the Pittsburgh Equitable Meter Co., 400 N. Lexington Ave., Pittsburgh, Pa.

Line Traveling Pipe Coating and Wrapping Machine



A recent "Bitumastic Bulletin" contained a description of Wailes-Dove-Hermiston's interesting new line—traveling pipe coating and wrapping machine. This machine actually rides on the pipe while applying the molten protective coal tar enamel. It travels up and down hill and around bends with the same ease as it does on the level.

This machine was designed with the objective of precision coating of uniformity and minimum waste of materials. Its performance represents several new ideas in pipe line coating technique.

The machine consists essentially of a sump tank into which the hot coating material is pumped from a heating kettle. This material is then pumped up into a ring which surrounds the pipe at a clearance of several inches. The coating is flooded under pressure upon the pipe through many holes located on the inner face of the ring. The coating flows over the entire surface of the pipe in a plane at right angles to the center line of the pipe, the excess material falling back into the sump. Simultaneously, the coated pipe is spirally wrapped.

The machine is propelled by a gasoline engine. An interesting feature of the machine is its ability to apply a double coating of enamel on the underside of the pipe and part way up each side. The remainder of the pipe is coated with marked uniformity and economy of coating materials.

INCINERATION ENGINEERS

NICHOLS ENGINEERING & RESEARCH CORPORATION

60 WALL TOWER NEW YORK, N. Y.

Consultants • Designers • Constructors

"Micromet"

A New Product for Scale Prevention and Corrosion Control in Small Water Systems

• A new product, Micromet, designed to prevent scale, eliminate "red water" and control corrosion in household water systems, air conditioning units and in small systems generally is being offered by Calgon, Inc. of Pittsburgh, Pa. On a developmental basis this product has already been in use for a year or more.

The use of glassy phosphates in municipal water and industrial cooling systems to prevent scale formation from hard, high-bicarbonate water, "red water" caused by precipitation of dissolved iron from well water and to control corrosion induced by soft, corrosive water, has been well established for some time. These problems, however, are not confined to large water systems. Serious troubles develop in hot-water heater coils, tanks and lines in millions of private homes and small buildings, as well as in air-conditioning units and mechanical dish, bottle and can washing equipment. To meet the need for a slowly soluble phosphate glass that could be readily administered continuously in the minute quantities required in the treatment of small systems, Micromet was developed.

Micromet is a glassy sodium phosphate, made of food-grade material to a closely controlled composition, and carefully crushed and sized. When placed in cold water it dissolves at the rate of 25 per cent *per month. The* usual feed necessary to correct scale, corrosion and "red water" troubles is only 5 parts per million of water, or 1 pound to each 24,000 gallons of water. As the average small home uses approximately 6,000 gallons per month, a feed of only 4 ounces of Micromet per month is required.

Micromet is fed into water lines by means of a simple pot-type feeder —individually made of standard galvanized or black iron pipe by the local plumber to conform to the requirements of the individual system. Micromet will be distributed in units of 1, 1½ and 5 pounds and to all those concerned with problems of scale prevention and corrosion control it offers much because of the simplicity and economy of installation and treatment, and its effectiveness.

Calgon, Inc. has produced a 12-page booklet which gives detailed information on Micromet installation and treatment for the correction of scale, corrosion and "red water" in a variety of specific cases where these troubles are encountered. Requests for a copy should be directed to Calgon, Inc., 323 Fourth Ave., Pittsburgh, Pa.

BUY DEFENSE BONDS AND SAVINGS STAMPS

Each is in the picture of

DARCO PURIFICATION

With 20 years' experience in making activated carbons of all kinds—for many types of purification—Darco is in a position to give waterworks men real help in removing tastes and odors.

Performance tests prove that Hydrodarco delivers maximum palatability control per dollar. When you buy Hydrodarco, you may pay a little more — but you get a lot more in carbon performance.

Join the alert waterworks men who have found that a small difference in price per pound may mean a large difference in odor-removal efficiency. We will be glad to send you complete details, along with a sample of Hydrodarco.

HYDRODARCO
Reg. U. S. Pat. Off.

HYDRODARCO

ATTEND THE CONVENTION
Chicago, Illinois — June 21-25

DARCO

DARCO CORPORATION

60 East 42nd Street, New York, N. Y.

DISTRIBUTING POINTS: New York • Buffalo • Cincinnati • Chicago • St. Louis • Kansas City • San Francisco • Los Angeles • Marshall, Texas

New Chemical Proportioning Control Unit by Graver

• The Graver Chemical Proportioner is a new unit for regulating the feeding of chemicals in proportion to the volume of water, sewage, etc., being treated, providing an accuracy of proportioning within 2 per cent under all conditions.

Any standard type of flow measuring device such as venturi, orifice, propeller, or disc water type meter, which can be equipped with a contactor, may be used to operate this Proportioner. The impulse set up by the contactor is transmitted electrically to the Graver Proportioner which is set into motion and lowers the swing pipe or skimmer into the chemical solution in the tank, thus providing feed of chemicals in proportion to the flow of water through the flow measuring device which may be located remotely or nearby.

The Graver Proportioner consists of a standard make timer, relays, motor, reduction gear, and cable drum; all completely assembled in a control box which can be conveniently mounted on the shell of the chemical mixing tank. The timer used is of a variable type and is designed to operate the motor

drive of the proportioner for a predetermined length of time for each impulse received from the meter contactor. By simply adjusting the variator, which is part of the timer, the quantity of chemical fed is changed.

The drum on the Graver Proportioner, used for the lowering of the swing pipe or skimmer into the chemical feeder, is on the outside of the control box where it is readily accessible for attaching of the lowering cable and for the rewinding of the cable after the swing pipe or skimmer has been lowered to its maximum depth. The circular indicator is graduated to indicate the percentage of available chemical remaining in the chemical feeding tank. The Proportioner is also provided with a manual control, making it possible to operate the feeder manually in the event of the failure of the meter contactor, and also an external manual control, whereby the swing pipe may be lowered into the chemical feeding tank, in the event of electric current failure. Through an electrical contact a signal is given when the charge of solution within the tank is exhausted.

The contactor provided for the flow measuring device is designed to make a contact for any predetermined amount of water passing through the meter. The impulse from this meter contactor is transmitted through the relays to a small motor, which is controlled by the timer. The relays are so interlocked that in the event the meter stops, with the contactor closed, the proportionate equipment ceases to operate.

The proportioner is usually attached to the side of the chemical feeding tank. The meter containing the contactor, however, may be located at any distance from the chemical tank and proportioner.

Although the new unit was designed especially for attaching to Graver Chemical Mixing Tanks, it adapts itself to general use whenever a swing pipe can be installed in a solution tank.

A new Bulletin (No. 310) presents the new Proportioner in greater detail. For a copy write Graver Tank & Mfg. Co., 5008 Tod Ave., East Chicago, Indiana.

with *Reilly* Primer and Pipe Enamel

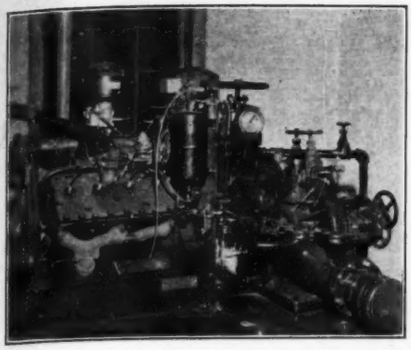
● Gas, oil and water lines coated with REILLY Primer and Pipe Enamel are lastingly protected under all conditions of soil and climate. REILLY Enamel bonds firmly to the metal, providing a smooth, tough coating that effectually resists abrasion and soil stress, withstands extremes of temperature, and prevents corrosion caused by moisture, electrolysis, soil acids and alkalis . . . On the inside of water mains and conduits the smooth, mirror-like REILLY lining prevents incrustations and tuberculation and assures permanent full-capacity flow . . . REILLY coal tar paints give equally effective and economical protection to tanks, stacks, structural steel and all metal exposed to atmosphere, corrosive vapors and gases . . . Booklet describing REILLY protective coatings sent on request.

Reilly
COAL TAR PRODUCTS

17 PLANTS
to Serve the Nation

REILLY TAR & CHEMICAL CORPORATION
Executive Offices: Merchants Bank Building, Indianapolis, Indiana
2513 S. DAMEN AVENUE, CHICAGO, ILLINOIS 500 FIFTH AVENUE, NEW YORK, N. Y. ST. LOUIS PARK, MINNEAPOLIS, MINN.
SEVENTEEN · PLANTS · TO · SERVE · YOU

New Special Duty Pump Units Developed for Small Plants and Towns



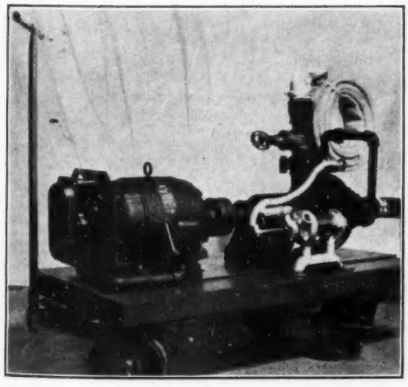
New F.M. Engine-Driven Approved Fire Pump.

• Dangers of incendiary bombs has brought to home owners, factory managers and municipal officials alike the importance of ever-ready pumping equipment in case of fire.

Recently developed fire pumping units by Fairbanks-Morse now afford small plants and towns adequate fire protection at a moderate cost. In the past small plants and municipalities have found that standard pumping station equipment has been too expensive and too complicated for their means and needs.

One of these new Fairbanks-Morse Pumping Units, approved by the Underwriters Laboratories was recently installed in Delavan, Wisc. It is composed of a four-inch Figure 5813 F-M Fire Pump driven by a Ford-Mercury Engine. The Mercury Engine drive, turning at 2500 RPM, is of sufficient speed to be direct connected, eliminating the expense of gear drive necessitated when a slow speed engine is connected to a high speed pump. This simplicity represents a great saving in installation and maintenance costs over regular fire pump units. As an added advantage, there are service stations with stocks of replacement parts for the Ford engine in practically every village in the country.

Portable Pumping Units



New F.M. Portable Pumping Unit.

In response to considerable demand, Fairbanks-Morse has also developed a portable pumping unit which may be adapted to a variety of service, municipal and otherwise.

A good example of this type of unit was recently assembled for Waverly, Ohio. A 2-inch non-clogging F-M sludge pump was direct connected to a 3 HP F-M splash-proof motor and mounted on a standard warehouse truck with 8-inch rubber-tired wheels.

The pump is primed by means of a hand-operated bracket-type pump mounted on a truck platform with its suction connected to the top of the volute through a ¾-inch pipe line equipped with a shut off valve. The sludge is picked up through a length of 2½-inch wire-lined rubber suction hose and discharged through a length of 2½-inch collapsible cotton fabric hose.

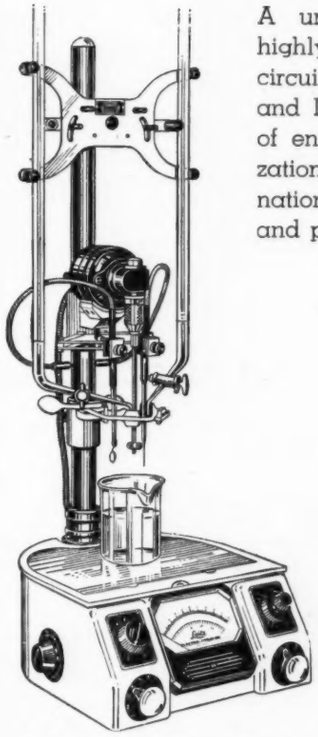
The discharge hose is fitted with a gate valve to control the head under high suction lift conditions and to seal the discharge of the pump during priming operations.

Such a unit—which can be used with other F-M pumps as well as with the sludge pump—meets a variety of needs. On construction projects, at any place where temporary drainage is necessary, and for any number of other tasks where a portable pump is required this compact unit seems ideal.

For further details write Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago, Ill.

Leitz

"G & D" ELECTRO-TITRATOR



Leitz "G & D" Electro-Titrator

Made in U. S. A.

A universal Electro-Titrator using a highly stable and sensitive voltmeter circuit designed by Dr. R. L. Garman and Dr. M. E. Droz for determinations of end-points in electrometric neutralization titrations (including pH determinations), oxidation-reduction titrations, and precipitation titrations.

Some of its outstanding advantages are:

1 Variable sensitivity up to a maximum of 40 millivolts per inch of needle deflection;

2 Battery operated with a power consumption of as little as 0.25 watt; fluctuations in the power supply are completely eliminated;

3 Variable speed of the stirring motor;

4 A clearly visible meter with a scale, 3⅛" long, permits continuous reading of the voltage changes throughout the entire progress of the titration.

Pamphlet No. 1283 Upon Request

E. LEITZ, INC.

730 Fifth Ave., New York, N. Y.

Branch Offices: Chicago, Washington, D. C.

Completed On Time!

"Never have so many, owed so much, to so few!"

That brilliant statement made by Britain's Winston Churchill can be applied to a case in our own country.

Today, millions of soldiers, sailors and marines are being supplied with an abundance of safe water from Layne built Well Water Systems. The Armed Forces can thank less than two thousand Layne Organization employees. In an amazingly short period of time, they undertook—and *completed on time*—the most gigantic Well Water System building task ever accomplished in this, or in any other country. These widely experienced men located water bearing sands, drilled wells in almost every type of earth formation and set tons of casing. Furthermore they built the pumps, made installations and placed their water systems in operation—producing hundreds of millions of gallons of water daily.

Such outstanding service, performed without delay or failure, has created a brilliant chapter in the long and successful career of the Layne Organization. No greater commendation for ability, speed and efficiency could be offered.

LAYNE & BOWLER, INC.
Memphis, Tenn.

LAYNE
PUMPS & WELL WATER SYSTEMS

Affiliated Companies

Layne-Arkansas Company.....Stuttgart, Ark.
Layne-Atlantic Company.....Norfolk, Va.
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Layne-Louisiana Company.....Lake Charles, La.
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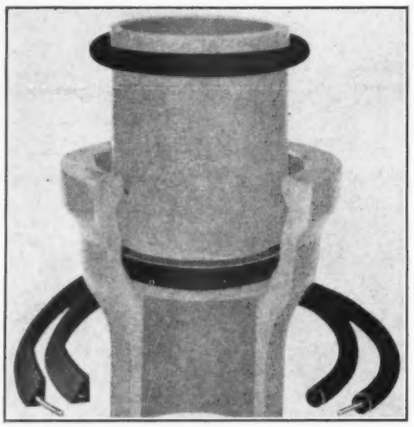
Layne-Ohio Company.....Columbus, Ohio
Layne-Texas Company.....Houston, Texas.
Layne-Western Company.....Kansas City, Mo.
Layne-Western Co. of Minn.....Minneapolis, Minn.
International Water Supply, Ltd...London, Ont.

WORLD'S LARGEST WATER DEVELOPERS

Rubber Jointing Material Still Available

And Now Offered in Improved Form

● It almost sounds like a "Believe-it-or-Not" story, but announcement has been received of the continued availability to the water works field of "Flexo-Pac" rubber joint packing, and in improved form.



The new wedge shaped "Flexo-Pac", as well as the tubular shape, is now being offered, (apparently without restrictions) in four separate sizes to cover the entire range of B&S pipes down to 2 inch diameter and up to the largest sizes produced.

The wedge shaped product now has one side flat—the side that is placed next to the spigot end of the pipe. It comes with a hole through it to facilitate the making of "Flexo-Pac" rings, if the user perfers rings to the overlap method of installing this rubber "yarn". The same is true of the tubular shape, the rings being made by cutting the material to scant pipe circumference lengths and joining the two ends by inserting a 2½" length of ordinary No. 9 wire in the hole in one end and pushing the other end onto this soft wire "coupling". These rings, which take less material than does the overlap method of yarning, are slipped over the spigot end of the pipe which is then centered in the bell and shoved home. The ring is then driven up against the bead with a blunt yarning iron.

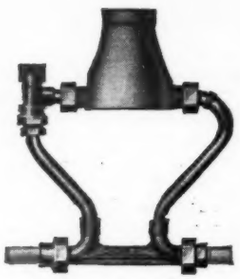
Both shapes, in the four sizes of each, are now put out in coils of 125 ft. to 200 ft. lengths, similar to coils of braded hemp. It is claimed that the cost per joint for this sanitary pioneer rubber packing is practically the same as for the ordinary braided jute.

For more information in detail, and listed prices, request the new "Flexo-Pac" bulletin, FP.-142, from The Eclat Rubber Co., Akron, Ohio.

BUY DEFENSE BONDS AND SAVINGS STAMPS

The **FORD COPPERSETTER**

A complete meter mounting, all brass and copper, for service lines of moderate depth.



The COPPERSETTER replaces meter couplings, valve, risers and ells. It saves the making of joints. Installed as a unit, it requires no meter blank or measuring to leave the proper space for meter.

There is nothing to rust out on the COPPERSETTER. It cuts down pressure loss, assuring full flow through the meter. Meter changes are easy and trouble-free as the removal of the meter leaves the service pipe on inlet and outlet physically connected and held in line, the electrical bond unbroken.

COPPERSETTERS are made in heights from 6" to 36", with and without valve, for connecting to iron or copper pipe. Learn more about these modern fittings.

Send a postal card for our catalog. No obligation.

FORD METER BOX CO.,
WABASH, IND.

WITH THE MANUFACTURERS

Two Important Manufacturers Cooperate in Insuring Water Service Pipe and Fittings for Users

• A noteworthy development, representing some careful planning and foresightedness on the part of two important manufacturers to alleviate shortages in water pipe and connections, has come to our attention. What has been accomplished deserves commendation when one realizes that this is not the time when business is so poor that these large companies were pushed into the job that was undertaken.

American Smelting's Type K, "Tube-Loy" tubing has been increasingly used as a water service pipe. And, its presence in the market, during these difficult times, has, in many instances, solved the problems of contractors, water works superintendents, city engineers, and others. This product, installed most widely with the use of ordinary copper compression fittings, was somewhat endangered by the fact that there were indications that even these copper fittings would become unavailable.

American Smelting and Refining Co., in conjunction with the Grinnell Co., of Providence, R. I., immediately worked together to develop a special "Tube-Loy Fitting," made from galvanized malleable iron, which would be perfectly suitable for permanent use, and also improve the design of connections previously used. These fittings are now being manufactured and are available for use with Type K "Tube-Loy."

These two companies, working cooperatively, have seen to it that water service pipe for use from main to meter, together with an excellent fitting for its proper installation, will continue to be available to those who have need for such mediums.

Looking at the situation as it exists we are of the opinion that this is the sort of will to do that is to win this war.

Worthington-Gamon Elects Officers

• Harry C. Beaver has been elected president of Worthington-Gamon Meter Co., as successor to the late E. T. Fishwick. Mr. Beaver is also president of the Worthington Pump and Machinery Corp.

R. R. Anderson, treasurer and manager of Worthington-Gamon Meter Co., has been elected vice president and director, as well as retaining his office as treasurer.

Permanent

REDWOOD PIPE Saves critical materials! Long known as a pipe with greater carrying capacity than metal or concrete. Does not clog, scale or pit.

LOWER labor, installation and maintenance costs. Long life, no electrolysis, contamination of water, or destruction by sulphur, salt water or other mineral impurities. New type Wyckoff California Redwood Pipe for water supply and sewage lines is a proven product.

A. Wyckoff & Son Company

ELMIRA, N. Y.

Originators of Machine Made Wood Pipe

1855 — Our 87th Anniversary — 1942

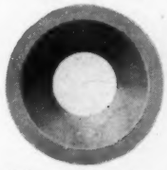
THE NATIONAL METHOD • OVER 35 YEARS EXPERIENCE

GUARANTEED TO RESTORE 95% ORIGINAL CAPACITY

DEFENSE DEMANDS

FULL CAPACITY MAINS

Before Cleaning



After Cleaning

MANY cities that now find their water supply resources sadly overtaxed by the additional thousands of water users in defense industries and nearby army training camps, are turning to the *NATIONAL METHOD of water main cleaning* as an economical means of improving water service.

Cleaning by THE NATIONAL METHOD restores clogged mains to at least 95% of their original carrying capacity, making unnecessary large expenditures for auxiliary pipe lines, increased power at the pumps, new standpipes, etc.

The NATIONAL METHOD

The National Water Main Cleaning Co.

30 Church St. Branches: New York

115 Peterboro St., Boston, Mass. — 406 Fla. Theatre Bldg., Jacksonville, Fla.
910 William-Oliver Bldg., Atlanta, Ga. — 205 W. Wacker Dr., Chicago, Ill.
7103 Dale Ave., St. Louis, Mo. — 501 Howard St., San Francisco, Calif.
3812 Castellar St., Omaha, Neb. — 2028 Union Ave., Montreal, Can.

Fig. No. 236

The Pace Setter

"Varec"

APPROVED

WASTE GAS BURNERS

ASSURE Maximum SAFETY

Scientifically designed with adjustable air intake in the mixing chamber, "VAREC" approved Waste Gas Burners have found wide usage whenever disposal of surplus sewage gas presents a problem. The long, heavy cast iron stack insures proper draft and complete combustion.

"VAREC" approved PRESSURE RELIEF with VACUUM BREAKER VALVE and FLAME ARRESTER

Fig. No. 58C

Installed on digester and gas holder domes, it affords emergency pressure and vacuum relief. Stops flame propagation. Equipped with noncorrosive telescopic flame arresting element for easy inspection and maintenance.

Other "VAREC" Products

Flame Trap Assemblies • Pressure Relief and Vacuum Breaker Valves • Flame Arresters • Flame Checks • Regulators • Check Valves • Drip Traps • Manometers • Explosion Relief Valves • Manhole Covers • Sample Hatches.

The Vapor Recovery Systems Company

Compton - - - - California

Branch Offices—Stocks carried at New York City Houston, Texas — Tulsa, Oklahoma Agencies Everywhere

R. F. Bergmann Becomes Link-Belt Chief Engineer

R. F. Bergmann

• Announcement is made by Link-Belt Company that Richard F. Bergmann has been appointed Chief Engineer for the company, with office at executive headquarters in Chicago.

Mr. William W. Sayers, has been with the company for 39 years and Chief Engineer since 1925, has been appointed Consulting Engineer. In this newly created position he will continue to deal with patent matters and be available for consultation.

Mr. Bergmann was assistant to Mr. Sayers from 1933 to 1936, when he resigned to become chief engineer of Rayon Machinery Corp., Cleveland, Ohio, from which position he now returns to Link-Belt. He is a native of Logansport, Ind., and was graduated from Rose Polytechnic Institute at Terre Haute, Ind. in 1918, and joined Howe Chain Co., Muskegon, Mich.

New Leak Detection Main and Valve Box Locating Service

• S. F. Ferguson, long identified with the line of Universal Water Leak Detectors and Pipe Locators, is offering a specialized leak survey and main or valve locating service of particular interest at this time when extra water and pressure demands must be met, water must be conserved and accurate knowledge of valve location was never more important.

Mr. Ferguson, has fully equipped a special car with a complete lot of instruments and apparatus for leak detection and spotting and valve and main location surveys. This car is used to give rush service and in answering emergency calls. The availability of this service to the smaller towns is of especial interest.

Mr. Ferguson has established headquarters in the Douglas Hotel Bldg., Newark, N. J. and in addition to offering the new survey service is eastern distributor for the "Universal" line of Leak Detectors and Pipe Locators.

Navy "E" Awarded De Laval Co.

• In a letter announcing the award of the Navy "E" to the De Laval Steam Turbine Co., Trenton, New Jersey, Secretary of the Navy Knox congratulates the workers and management upon their significant contribution in production toward winning the war. The plant will be authorized to fly the prized Navy "E" pennant and employees will be privileged to wear the Navy "E" lapel insignia.

WATER TREATING EQUIPMENT

Gravity and Pressure Filters, Softeners, Recarbonators, Chemical Diffusers, Cooling Towers, Standard and Special Equipment for any Water Treating Problem

MUNICIPAL SERVICE CO.

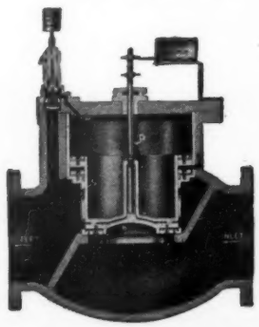
Dwight Bldg., Kansas City, Mo.

Electric Double Cushioned Check Valve

This valve is for use in connection with remote tank storage service with valve located adjacent to motor centrifugal pump, also where a high-low pressure or float-operated switch located at tank is wired to the valve in order to accomplish complete automatic sequence of operation for starting and stopping the pump with respect to storage water levels.

Sizes 3" to 36", angle and globe patterns.

Write for specifications.



GOLDEN-ANDERSON VALVE SPECIALTY CO.

Fulton Building Pittsburgh, Pa.

Neptune Loses Veteran Service Manager

• Andrew C. Koopman, long time manager of the Service Department of Neptune Water Co. collapsed in his office of the Long Island City factory on May 15th and died shortly after in a hospital.

Mr. Koopman had been connected with Neptune for the past 34 years and in the Service Department for 24 years of this time. He was one of Neptune's most valued veteran employees.

Omega in New Offices

• Omega Machine Co. of Kansas City, Mo., manufacturers of chemical feed equipment, this month moved into their new and more spacious office and factory building. The new address of Omega is 3409 E. 18th St. Telephone Benton 2602 and 2603.

Dr. Lewis Miller Joins Betz Staff

• Dr. Lewis B. Miller has joined the consulting staff of W. H. and L. D. Betz, Chemical Engineers, Philadelphia, Pa. Dr. Miller was graduated from the State University of Iowa with a Bachelor's and Master's degree and received his Doctorate from Columbia University. He has been engaged in research on problems relating to water purification and sewage disposal and is the author of 35 papers, most of which deal with industrial process water problems. He is a member of committee D-19 of A. S. T. M. and Chairman of the water committee of T. A. P. P. I.

In the muncipal water supply field Dr. Miller will be remembered for his early studies of the chemistry and behavior of precipitates (floc) from aluminum salts, in which was proven the value of the bi-valent sulphate ion (SO_4) over the mono-valent ions in coagulation with aluminum salts.

Foxboro Employees Observe 25-Year Milestone

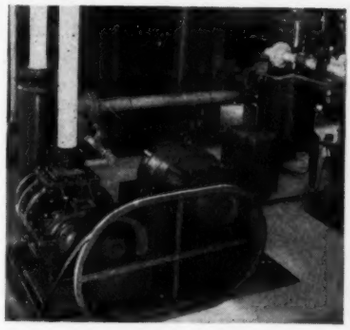
Employees of The Foxboro Company who have completed 25 years or more in its service were guests of the Company at a celebration, held at the Main Office, Foxboro, Mass., on the evening of May 26th. A jeweled service pin of gold was presented to each of the 50 men and women thus honored, and a program of entertainment, supplemented by the reminiscences of old-timers, made the occasion an enjoyable one.

Almost another 50 employees have service records which are within a few months of the quarter-century mark; and it is therefore assured that similar celebrations will be held annually, hereafter, to welcome new members as they qualify.

The Foxboro Company, makers of instruments for process measurement and control, was organized in 1908 as the Industrial Instrument Company, but adopted its present name in 1912.

THE TASK of *Superior Performance*

"R-C" Vacuum Pump installed on filters for dewatering sludge, producing 20 inches of mercury vacuum.

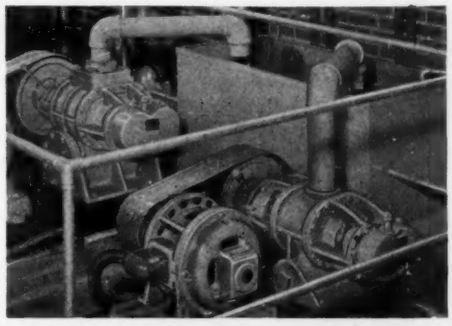


National survival calls for the CREAM of industrial equipment to shoulder the burden of production.

"Superior performance" has long been a characteristic of Roots-Connersville Blowers and Vacuum Pumps, based on sound engineering and built-in ruggedness that keep them dependable and efficient—even under today's non-stop, peak-plus production requirements.

Since National survival comes FIRST, the cooperation of our customers is earnestly requested when their orders cannot be handled as promptly as in normal times.

ROOTS-CONNERSVILLE BLOWER CORPORATION
206 Mount Avenue Connersville, Indiana



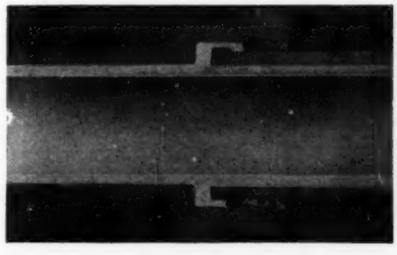
"R-C" Vacuum Pumps used for priming Centrifugal Pumps at a Colorado water works.

Roots CONNERSVILLE SINCE 1854

Improved Moderate Speed VACUUM PUMPS

View showing Tate Process in Pipe Joint. Note thoroughness of Lining.

Help Save Critical Materials · investigate **TATE Cement Lining Process**



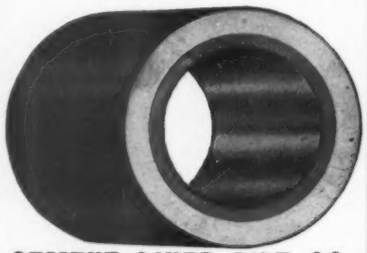
With the increase in demand for Critical Materials in the Water Works field *now* is the time to investigate the Tate Cement Lining process—and see what it can do to restore the efficiency of your old water mains.

THE TATE PROCESS ACCOMPLISHES

1. Water mains cleaned and cement-lined without removing pipe.
2. Eliminates discoloration and further cleaning costs.
3. Reduces pumping costs.
4. Restores reduction in head and flow co-efficients. This means full fire protection and lowered insurance rates.
5. All joints cement-lined . . . just one continuous pipe.
6. Does the job without interruption of service to consumer.

Write for Literature

TATE PIPE LININGS, Inc.
ANDOVER, MASS.

THE LINING IS IMPERVIOUS
THE JOINTS ARE LAPPED
LIPCO PIPE
AVAILABLE *Now!*
Immediate DELIVERY
ON
STEEL, TONCAN IRON
AND WROUGHT IRON
Cement Lined Service Pipe

CEMENT LINED PIPE CO.
Lynn, Mass.

ODOR and . . . TASTE
ARE HEALTH FACTORS-TOO
THE WATER SUPPLY that pleases nose and palate is an important contribution to community health — people drink more of it.
ESOTOO* is the answer to a simple, sure and more economical method of controlling residual chlorine — especially in "break-point" chlorination.
ESOTOO* is the Ideal De-Chlorinator.
Write for bulletin which describes the "Virginia Method" of applying Liquid Sulfur Dioxide for De-chlorination.
*ESOTOO is "Virginia's" Trade Name for Liquid Sulfur Dioxide.
VIRGINIA
VIRGINIA SMELTING CO.
WEST NORFOLK, VIRGINIA

LITERATURE AND CATALOGS

"Protection and Maintenance of Water Supplies Under War Conditions" is the title of Sanitary Engineering Bulletin No. 1 just issued by the U. S. Office of Civilian Defense for nation-wide distribution. This 40-page document has been compiled as a guide for water supply authorities (and others concerned) in planning protection of water systems in advance and restoration of water service should bombing or sabotage occur.

The bulletin discusses at some length the legality and operation of the Mutual Aid Plan, as set up in several states for the purpose of cooperative aid and supplying of water works materials and assis tance between neighbor communities in emergencies. It outlines the duties of State and Zone Water Coordinators and the organizing and development of Mutual Aid Plans within zones; the Central Inventory method of ascertaining sources of materials and equipment in each zone; outlines expansion and training programs for emergency; discusses the setting up of Emergency Region Depots and "The Water Works Organization in Relationship to the Defense Organization" as a whole. A number of organization charts are reproduced to indicate "who's who" and how every utility and public service fits into necessary actions in and following an air raid or other disaster. The appendix contains suggested advice and information to distribute among water consumers which is "Ten Home Water Supply Precautions." A procedure for main sterilization is also given. For copies of Sanitary

Complete Sewer Cleaning Equipment
Before you clean your sewers, don't fail to investigate our equipment. We supply a complete line of sewer cleaning apparatus—machines, sewer rods, cleaning tools. Machines may be purchased or leased.
Sewer rods and hand tools sent on free trial.
Manufacturing Sewer Cleaning Equipment Since 1901
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Water Treatment
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Sludge Conditioning
FERRI-FLOC for water and sewage treatment. Results show large savings in cost of coagulation. Widely used to condition sludge.
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VALVES
HYDRANTS
AND WATERWORKS ACCESSORIES
M & H products, including pipe line accessories, are well known for high quality of material and expert workmanship. They are made according to standard specifications and have been used for many years throughout the country. Write for Catalog No. 34.
M&H VALVE
AND FITTINGS COMPANY
ANNISTON, ALABAMA

Engineering Bul. No. 1 write the U. S. Office of Civilian Defense, Washington, D. C. (Your State Sanitary Engineer may be able to supply copies also.)

"Transite" Pipe in War Damage and Emergency Repairs is a Johns-Manville publication of 92 pages expressly produced to inform Transite pipe users of the most effective and rapid method of repairing (temporarily and permanently) damage to mains of "Transite." Likewise, however, the methods are applicable to the repair of damage to metallic mains in which the ease of cutting and handling of the light weight "Transite" pipes and couplings prove advantageous in emergency operations. Several methods of preparing for possible damage to mains, and of making each repair, are outlined in order that the scheme and materials most suitable for the individual situation may be employed.

In the fore part of the book is a collection of pictures showing actual European experiences with destruction of mains and sewers and evidence is presented that the flexible "Transite" jointing, subject to give and take, were responsible for the sparce damage to the asbestos-cement pipe lines when more was to be expected from the nearby bomb hits.

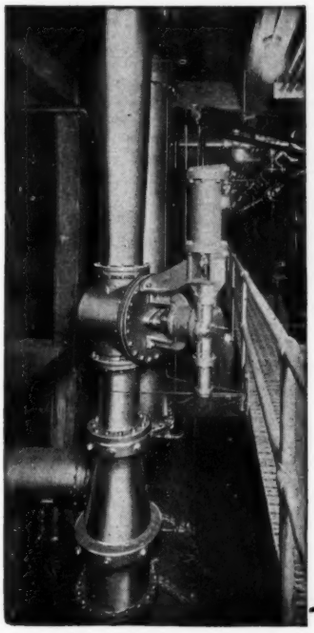
Typical bomb damage to mains are sketched from observed happenings, and a plat shows the distribution of bomb hits on a system. Then follows many detailed pages of methods available for making repairs, installing temporary lines, etc. A copy of "Transite Pipe Repairs for War Damage" may be obtained from any Johns-Manville office or at headquarters, 28 East 40th St., New York City.

"Taste and Odor Control," published by the producers of "Nuchar"-activated carbon, makes its reappearance in thickened, revised form—a booklet of 92 pages of information assembled as an aid and service to those faced with taste and odor problems in water supply, and desirous of doing something to correct such conditions rather than combine to explain it away by placing the blame on "Little Algy," or on upstream industry.

Not alone does the new compendium of information deal with application of carbon for correction but also contains chapters on such methods as "Super-Chlorination," "Chloramination," "Ozonation" and "Permanganization." An interesting lead-off chapter contains a con-

Which Primary Element?

VENTURI TUBE, FLUME, WEIR, ORIFICE, OR NOZZLE



The primary element for your metering application should be selected not arbitrarily but by the requirements to be fulfilled and by the economic considerations entering into the installation.

Sewage and sludge are often, though not always, measured by Venturi Tubes, Flumes, or Weirs.

Water may be satisfactorily measured by any type of primary element. Factors such as the cost of pumping, the pressure and the size of pipe or channel usually dictate the device used.

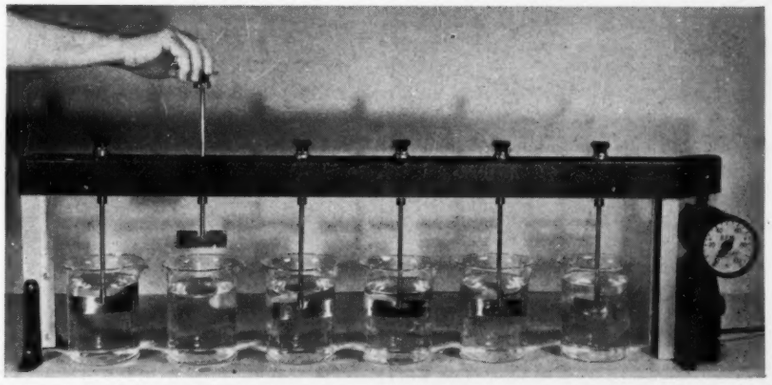
Steam is usually measured by the Bailey Orifice or Flow Nozzle.

Bailey Meter Company holds no brief for any particular primary element, its only interest is in making sure that the user secures the highest accuracy and reliability at the lowest expense.

Detailed information on the advantages of various types of primary elements furnished on request.

MU-18

BAILEY METER COMPANY
1072 IVANHOE RD., CLEVELAND, O.
Bailey Meter Company Limited, Montreal, Canada



THE *Phipps & Bird* LABORATORY MIXER...

IS the important piece of equipment in the Modern Water Works Laboratory. Now being used by leaders in water works research. Many superintendents and chemists have been able to reduce their chemical costs by the control of chemical dosages with this mixer. Write for literature.

PHIPPS & BIRD, INC.
RICHMOND, VA.
"SOUTHERN CENTER FOR LABORATORY APPARATUS AND CHEMICALS"

densed history of "Ancient and Modern Water Supplies" by W. W. Hassler of the University of Penna. Turre of Denver presents a worthy description of the common forms of algae, excellently illustrated, and revealing the odors and other difficulties created by the individual forms. The Bailey method of "Black Out Control," in *prevention* of algae growth, represents one of the recent effective applications of carbon to cut off growth-promoting sunlight in open basins and reservoirs. Chapters deal with most effective points of carbon application and dosage selection, and the important matter of storage, handling and feeding. "Taste and Odor Control" is a booklet that every water purification man should request, and read carefully. For a copy write "Nuchar" Division, W. Va. Pulp and Paper Co., 230 Park Ave., New York.

Foxboro "Rotax" Electric-Operated Pumping and Chemical Feed Control is described and illustrated in their new bulletin, No. B-294. The major part of the text is devoted to the varied uses of indicating and recording controllers in water works and sewage engineering. Efficient controls for altitude tanks, reservoirs, deep wells, and distribution flows are described in detail. Among the Foxboro instruments designed for use in water and sewage treatment plants are controllers for operating chemical feeders regulating the chemical dose in ratio to flow. The bulletin contains several schematic diagrams of typical pumping installations, photographs of equipment and specimen chart records. To obtain a copy of Bulletin B-294 address the Foxboro Company, Foxboro, Mass.

A New Handbook on the Care of Motors has just been published by Allis Chalmers of Milwaukee. This "Guide to Wartime Care of Electric Motors" takes a fresh, new

WATERPLUG

1. For control of water pressure when running or seeping through cracks and other defects in masonry.
2. For caulking and sealing around pipes or other appliances which pierce masonry walls of tanks, sludge basins or foundations.
3. WATERPLUG is prepared ready for use by the addition of mixing water only. It hardens quickly and is permanent.
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5. Troublesome water problems can be solved quickly and permanently.

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HYDRO-TITE

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HYDRO-TITE joints are strong, very flexible and tight.

Write for our free trial offer.

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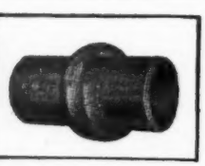
WESTON



GASKET AND FORM
The Perfected Method for Making SEWER PIPE JOINTS OF CEMENT

- **No jute used—gasket centers spigot.**
- **Definite space in each joint for cement.**
- **Form confines cement-grout to lower portion of joint.**
- **Particularly advantageous in water-bearing trenches.**
- **Infiltration minimized.**

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ELEVATED STEEL TANKS

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Write for Catalogue and Information

IOWA VALVE CO.

General Offices:
Hubbell Bldg., Des Moines, Iowa

Plant:
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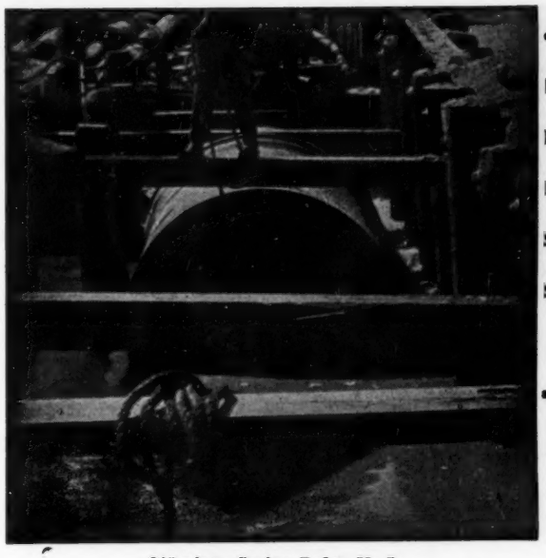
slant at the subject of motor care under heavy load war conditions and scarcity of replacements. In addition to its value to plant engineers and maintenance men it possesses particular value in training new men. The book is obtainable upon request to Allis-Chalmers, Milwaukee, Wis.

"How to Solve War-Time Drainage Problems" is the caption on a timely folder recently published by the Armco Drainage Products Association, describing their new "emergency pipe" as a substitute for products requiring critical war materials. The new drain pipe is constructed entirely of short lengths of wood assembled at the factory into light but sturdy octagonal-shaped pipe sections. Wood dowels are driven into drilled holes, thereby eliminating the use of nails. The pipe has ample strength to meet engineering standards, reacting under a tamped fill in much the same manner as flexible metal pipe, and is recommended for essential culverts, storm sewers, underpasses, and conduits. The light weight material makes for easy handling and low installation costs. There is no field assembly except for the joining of long pipe sections, which can be done with unskilled labor. To obtain a copy of the folder write to Armco Drainage Products Association, Middletown, Ohio.



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Down-Draft Type MECHANICAL SEWAGE AERATORS

Write for information on AER-O-MIX for your SEWAGE or WATER TREATMENT APPLICATION.

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INCORPORATED

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Prevent wear and cutting of rods, plungers, shafts and valve stems by using

MABBS RAWHIDE PACKING

In Your Water Works and Sewage Plants

IT LASTS LONGER—*Is Anti-Frictional, Saves Power, Labor and Repairs. Will prove the cheapest packing that can be bought.*

Trade Mark Reg. U. S. Pat. Off.

Mabbs Hydraulic Packing Co.

Incorporated 1892

431 S. Dearborn St., Chicago, U. S. A.

EDSON'S NEW HAND PUMP

Smallest Diaphragm Pump Made, 2" Suction Open Discharge. Capacity 1400 G.P.H. Weight 50 lbs. Size No. 1.

THE EDSON CORP'N
49 "D" Street
So. Boston, Mass.

NEW YORK: 142 Ashland Pl., Brooklyn

Catalog "T" Gives Full Data, Also Edson Hand and Power Pumps, Suction Hose and Pump Accessories

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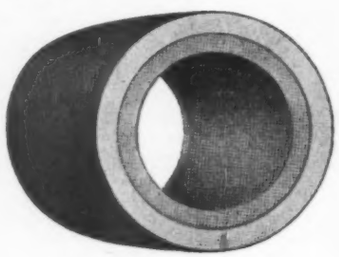

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Index TO ADVERTISERS

The Dash (—) Denotes Current Advertisers Who Do Not Appear in This Issue

Albright & Friel, Inc. ... 134
Alvord, Burdick & Howson ... 134
Aluminum Company of America ... 6
American Brass Company, The ... 276D
American Cast Iron Pipe Co. ... 120
American Norit Company, Inc. ... 8
American Smelting and Refining Co. ... 276B
American Well Works, The ... 12
Anderson Valve Corp. ... Data Section 57
Anthracite Equipment Corp. ... 135, Data Section 149
Armco Drainage Products Assn. ... —
A. S. G. Pipe Lining Co. ... 136
Atlas Mineral Products Co. of Pa., The ... 135, Data Section 107

Badger Meter Manufacturing Co. ... 9
Bailey Meter Co. ... 131, Data Section 33
Barrett Haentjens & Co. ... Data Section 50
Black & Veatch ... 134
Blake, Frank N. ... 135
Brainard & Co., F. S. ... 135
Buck, Seifert and Jost ... 134
Builders-Providence, Inc. ... 21, Data Section 34-35
Burns & McDonald Engr. Co. ... 134

Calgon, Inc. ... 32, Data Section 132
Carborundum Company, The ... 34
Carson-Cadillac Co. ... —
Carter Company, Ralph B. ... Data Section 191
Cast Iron Pipe Research Assn., The ... 268C
Cement Lined Pipe Co. ... 130
Central Foundry Company ... 119
Centriline Corporation ... —
Chain Belt Company ... 116
Champion Corporation ... 115
Chapman Valve Manufacturing Co. ... Second Cover
Chester Engineers, The ... 134
Chicago Bridge & Iron Company ... Data Section 82-83
Chicago Pump Company ... 268A, Data Section 232
Clark Controller Co., The ... —
Cole Manufacturing Co., R. D. ... Data Section 87
Clow & Sons, James B. ... —
Columbian Iron Works ... —
Connelly Iron Sponge & Governor Co. ... 136

Darco Corporation ... 123
DeLaval Steam Turbine Co. ... 36
Diamond Alkali Company ... 15
Dorr Company, Inc., The ... Third Cover
Dow Chemical Company, The ... Data Section 243
Dracco Corporation ... 118

Economy Pumps, Inc. ... 113
Edson Corporation, The ... 133
Electro Rust-Proofing Co. ... 120
Ferguson, S. F. ... 122
Flexible Sewer Rod Equipment Co. ... 114, Data Section 76
Flexible Underground Pipe-Cleaning Co. ... Data Section 76
Ford Meter Box Co. ... 126
Fulton, Edward A. ... 134

Gardner-Denver Co. ... 16
General Paint Corporation ... Data Section 66
Glace, I. M. ... 134
Golden-Anderson Valve Spec. Co. ... 128, Data Section 91
Graver Tank and Mfg. Co. ... 33, Data Section 155
Greeley & Hansen ... 134

Havens and Emerson ... 134
Hellige, Inc. ... Data Section 150
Hill, Hubbell & Co. ... Data Section 66
Homelite Corporation, The ... 121
Hydraulic Development Corp. ... 132, Data Section 103

Industrial Chemical Sales ... 268D, Data Section Facing Page 1
Innis, Speiden & Co. ... Data Section 244
Infilco, Incorporated ... 24, Data Section 140-141
Iowa Valve Co. ... 132

Jeffrey Manufacturing Company ... Data Section 182-183
Johns-Manville ... 10-11-39-117, Data Section 70-71-72-73

Knowles, Inc., Morris ... 134

Lakeside Engineering Corporation ... 114, Data Section 205
Lancaster Research Laboratories ... 134
Layne & Bowler, Inc. ... 126
Leadite Company, The ... 268B
Leitz, Inc., E. ... 125
Link-Belt Company ... 30
Lock Joint Pipe Company ... 14
Ludlow Valve Mfg. Co., Inc., The ... 20

M & H Valve and Fittings Company ... 130, Data Section 111
Mabbs Hydraulic Packing Co. ... 132
Macmillan Petroleum Corp. ... —
Mathews Hydrants ... 25
Mathieson Alkali Works, Inc., The ... 23
Metcalf & Eddy ... 134
Monsanto Chemical Co. ... —
Mueller Brass Co. ... 22, Data Section 131
Mueller Co. ... —
Municipal Service Co. ... 128

National Cast Iron Pipe ... —
National Lime Association ... 120
National Machine Works ... 7
National Technical Laboratories ... 276A
National Water Main Cleaning Co. ... 124, Data Section 75
Neptune Meter Co. ... 42
Newsom & Aldrich ... 134
Niagara Alkali Company ... 252AB
Nichols Engineering & Research Corp. ... 122, Data Section 249
Nortarup & Company, Inc. Data Section 108
Nussbaumer & Clarke, Inc. ... 134

Omega Machine Company ... 115, Data Section 161

Pacific Flush Tank Company ... Data Section 216
Peerless Pump Division ... 31
Pennsylvania Salt Mfg. Company ... 276C, Data Section 166-167
Permutit Company, The ... Data Section 161
Philadelphia Quartz Co. ... 135
Phipps & Bird, Inc. ... 131
Phoenix Meter Corp. ... 17
Pirnie, Malcolm ... 134
Pitometer Company, The ... 37-134
Pittsburgh-Des Moines Steel Co. ... 132, Data Section 84
Pittsburgh Equitable Meter Co. ... 4-5-244AB
Pomona Pump Co. ... Data Section 48-49
Portland Cement Association ... —
Proportioneers, Inc. ... 40, Data Section 166—Facing Page 169

Raisch and Associates, William ... 134
Ranney Water Collector Corp. ... 19
Reilly Tar & Chemical Corp. ... 124
Rensselaer Valve Co. ... 29
Riddick, Thomas M. ... 136
Roberts Filter Mfg. Co. ... 3
Roots-Connersville Blower Corp. ... 129
Ross Valve Mfg. Co., Inc. ... Data Section 88
Royer Foundry & Machine Co. ... Data Section 239
Runyon & Carey ... 135
Russell & Axon ... 136
Ryan Company, Fred J. ... —

Salomon & Bro., L. A. ... 8
Schramm, Inc. ... Data Section 81
Simplex Valve & Meter Co. ... 13, Data Section 42-43
Sirrine & Company, J. E. ... 135
Smith Company, S. Morgan ... 18
Smith Mfg. Co., The A. P. ... 35
Solvay Sales Corporation ... 119
Sparling, R. W. ... 133, Data Section 45
Standard Dry Wall Products, Inc. ... 132
Standard Silicate Division ... 15
Stanley Engineering Company ... 135
Stewart, W. H. ... 130, Data Section 175
Streamline Pipe & Fittings Division ... 22, Data Section 131
Stuart-Brumley Corp. ... 113, Data Section 142

Tate Pipe Linings, Inc. ... 129
Taylor and Co., W. A. ... 119
Tennessee Corporation ... 130, Data Section 196
Thomson Meter Company ... 42
Treasury Department ... 38

Underpinning & Foundation Co., Inc. ... 253
U. S. Pipe & Foundry Co. ... 260AB, Data Section 102

Vapor Recovery Systems Co. ... 128, Data Section 227
Virginia Smelting Co. ... 130
Vogt Brothers Manufacturing Co. ... —
Vogt Manufacturing Co. ... 133

Wallace & Tiernan Co., Inc. ... Back Cover, Data Section 168-215
Warren Foundry & Pipe Corp. ... 132
Water Leak Detector Co. ... 135
Weston, L. A. ... 132
Weston and Sampson ... 135
Whitman and Howard ... 135
Whitman, Requardt & Smith ... 135
Wilson Chemical Feeders, Inc. ... Data Section 162
Wood Company, R. D. ... 25
Worthington-Gamon Meter Company ... 117
Worthington Pump and Machinery Corp. ... 28
Wyckoff & Son Company, A. ... 127

Zeolite Chemical Co. ... 26-27

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1 WATER SUPPLY

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The contents represent matter carefully selected from the files of WATER WORKS AND SEWERAGE and other sources named in the text. In addition, a considerable effort has been made to secure the latest hydraulic tables and standards, and to present the most economical and modern methods.

Even though supplied at no charge to subscribers, beyond the regular subscription fee, the same conscientious work has been put into the preparation of this Data Section as would be expected in a book devoted exclusively to the same type of material, and published separately.

* * *

Note

All who become subscribers during the current year may have a copy of this special issue so long as the extra supply printed for the purpose lasts—and, at *no extra charge* above the regular subscription rate.

Old subscribers will note that a certain amount of material in this issue has appeared in earlier issues. With the constant influx of new subscribers in mind, useful tables and graphs and other basic data will be repeated each year, other material will be retained for use in alternate years, while some will be permanently replaced with new or revised material.

It will henceforth be our endeavor not to repeat more than one-half of the material from year to year. It will, therefore, be necessary for each subscriber to possess issues of two consecutive years if he is to have available what may be termed a "complete" file of WATER WORKS AND SEWERAGE Reference and Data Material.

L. H. Enslow

Editor.

REFERENCE AND DATA INDEX

Water Works and Sewerage

1942

A

Air at High Pressure Cleans Corroded Service Lines.248-250, Mag. Sec.
Air Chambers—for Relief from Water Hammer.....92-97
Air Chamber Requirements to Check Water Hammer..... 59
Air, Importance of, in the Activated Sludge Process.....203-204
Accounting—Joint Administration and Collection of Water and Sewer Accounts 169-171
Activated Carbon, in Taste and Odor Control.....148
Activated Sludge Bulking.....203-204
Activated Sludge Bulking Control.....202
Activated Sludge Plants—Location and Function of Meters.....194-195
Activated Sludge Process—Operating Fundamentals of 206-209
Administration and Collection of Water and Sewer Accounts 169-171
Age Factors for Cast Iron Mains..... 46
Agitators for Filter Beds 271-272 Mag. Sec.
Analyses of Sewage and Affluent 250-252
Areas of Circles.....279

B

Beams—I Safe Load Diagram.....273
Beams—Wooden Safe Load Diagram.....272
Bids, Pump: Simple Method of Evaluation.....110
Books on Water Works and Sewerage—A List of Representative Text Books, Handbooks, Journals, etc. 17-18
Branches—Number and Size Main Will Supply 106
Brass and Copper Pipe, Delivery Capacity and Pressure Drop 262-263
Bulking Control, Activated Sludge 202
Bushing, Saddle—Method of Preventing Corrosion on Trickling Filters 179

C

Cable, Yardage Wound on Reels or Drums.....276
Calgon Treatment at Bristol, Conn. .....269-270 Mag. Sec.
Capacity and Volume Equivalents..... 28
Carbon, Activated, in Taste and Odor Control 148
Cast Iron Mains—Age Factors..... 46
Cast Iron Pipe Dimensions and Hydraulic Radius Values..... 69
Centrifugal Pumps—Selection and Checking.....51-54
Chain Gage—For Weirs 31
Channels and Pipes—Flow Measurement in 19-32
Check Valve Slam, Eliminating 58-59
Chezy Formula—Water Flow 20
Chlorination Equipment for Emergency Use 163-165
Chlorine Dosage Control in Sewage Treatment.....211-214
Chlorine Ice Problem, Solving of 154
Clorine, Purging Air Diffuser Plates with.....210
Circles, Area Table.....279
Cleaning Water Mains.....77-79
Coefficient of Friction of Pipe Lines—Formulae for Finding.....67-68
"C" Coefficient—Values of..... 20
"C" Values—Simple Method of Finding..... 67
Concrete Pipe, Flow Computed by Mannings Formula.....268
Concrete Pipe, Flow Diagram for Kutter's Formula.....269
Condition of Mains—Determination of.....67-69
Copper Sulphate as an Aid to Sewer Maintenance and Sewage Treatment 197-198
Copper Sulphate—Killing Roots in Sewers.....198
Collection—Joint Water and Sewer Accounts 169-171
Compressed Air Used to Clear Corroded Service Lines 248-250 Mag. Sec.
Compressed Air Flushing of Small Mains..... 80
Compressor: Maintenance of 109-110
Control of Odorous and Destructive Gases in Sewers and Treatment Plants .....277-280 Mag. Sec.
Control of Taste, by Use of Activated Carbon.....148
Conversion Factors.....257
Corroded Service Lines Cleaned With High Pressure Air .....248-250 Mag. Sec.
Corrosion, Control, With Calgon.....269-270 Mag. Sec.
Corrosion, Indicators of Brass Corrosion.....133-138
Corrosion of Water Pipes, Mechanism of.....133-138
Corrosivity Indicator 160
Cost of Mains—Estimating the.....104-105
Costs, Pump Power: Simple Method of Determination.....110
Cost of Sludge Removal—Reducing.....240-241
Cradle, Meter, a Handy Gadget for Repair Shop.....127
Cylinders, Horizontal or Vertical, Contents of .....282-283 Mag. Sec.

D

Damp Water Pipe, Painting of.....130
Decimal and Equivalent Fractions.....279
Definition of Terms Relating to Pumping..... 54
Diagonal Pipe Run—Calculation of Length.....278
Diffuser Plate Purging—With Clorine Gas.....210
Diffuser Plates—Method of Dry Cleaning.....186
Discharge and Velocity Diagram—For Vitrified Clay Sewer Pipe.193
Discharge Measurements—With Orifices and Weirs.....19-29
Dressing Rig—For Vacuum Filter.....242
Drilling and Developing Deep Wells in Rock.....251-252 Mag. Sec.
"Dry Cleaning" Air Diffuser Plates.....186
Dry Feeders—Design, Maintenance, Operation.....139

E

Effluent, Analyses of 250-252
Electric Heat Solves Problem at Pumping Station.....126
Electric Power—Gallons of Water Delivered per K.W.H. at Various Heads 52
Electrical Circuits—And Protection of.....62-63
Electrical Units and Horsepower.....271
Electrical Units of Measurement.....60-61
Electricity—Practical A B C's of for Water and Sewage Works Man 60-65
Elevated Storage 85-86
Elevated Storage—Value of Elevated Tanks on Water Supply Systems 89-90
Elimination of Gas Hazards at Sewage Plant.....217-226
Engine Operation on Sewage Sludge Gas.....228-231
Engineering Data 257
Enslow Continuous Stability Indicator 159-160
Equipment, for Emergency Use in Chlorination.....163-165
Equipment for Handling and Storing Ferric Chloride.....245-246
Equipment, for Surall Meter Repair Shop.....124-126
Estimating the Cost of Mains.....104-105
Evaluation of Pump Bids by a Simple Method and Determination of Power Costs 110
Explosion Hazards at Sewage Plants.....217-226

F

Factors for Determining Chlorine Dosage in Treatment Plant 211-214
Feeders, Dry—Design, Maintenance, Operation.....139
Ferric Chloride—Handling and Storing.....245-246
Fertilizer and Fertility Values of Sewage Sludge.....254-256
Filter Bed Agitators, Palmer—Installation of.....271-272 Mag. Sec.
Filter Cloth—Rig for Replacing on Vacuum Filter.....242
Filter, Vacuum—Dressing Rig 242
Filter Washing—New and Old Methods.....143-147
Fittings and Valves—Resistance to Flow.....46-47

REFERENCE AND DATA INDEX

Water Works and Sewerage

1942

Fittings, Offset Chart for 45 and 60 Degrees....262
Fittings—Resistance to Flow of Water....69
Flame Traps, for the Elimination of Gas Hazards in Sewage Plants....217-226
Flash Drying and Incineration....247-248
Float Gage, for Weir Measurements....31-32
Flow and Concrete Pipes Diagram....268-269
Flow Diagram for Pipes....265
Flow Gage for Channels, Conduits, Sewers....177
Flow in Open Channels....19-20
Flow Measurement by Orifice Method....19-29-46
Flow Measurement—Water Sewage, Air....19-25
Flow Measurement by Orifice Method....267
Flow of Water—Friction, Power, Measurement....19
Flow Powergraph....264
Flow Problems—Diagram for Solving....68
Flow—Resistance of Valves and Fittings....46-47
Flow, Water—Rates for Various Uses and Fixtures....112-113
Flow, Water, Through W. L. and Steel Pipe....21-22-23
Flushing Sewers....176-177
Flushing Small Mains by Compressed Air....80
Fractions and Decimal Equivalents....279
Friction and Flow—Formulae....20-22
Fuses and Circuit Breakers....63

G

Gage, Flow—Maximum, for Channels, Conduit and Sewers....177
Gages, Measuring for Weirs....31
Gases, Destructive—Control of in Sewers and treatment Plants....277-280, Mag. Sec.
Gas Hazards at Sewage Plants—How to Eliminate....217-226
Gasoline—Novel Use in "Dry Cleaning" Diffuser Plates....186
Gas Engine Installations, for Use of Sludge Gas in U. S. A....228-231
Gas Engine Operation on Sludge Gas....228-231
Gate Valves—Care and Maintenance....238-240, Mag. Sec.
Grains per Gallon to Pounds per Million....Table 259
Grit Chambers—An Improved Method of Velocity Control in....184-186
Grounding of Electrical Circuits....63

H

Hammer (See Water Hammer)
Hammer, Water—Formulas....25
Handling and Transporting Pipes and Materials....106
Hazen-Williams Formula—Valves for "C"....20
Head, Capacity, Efficiency and Horsepower Chart....261
Head Loss Tables....21-25
Head Loss Through Valves and Fittings....69
Head—Measurements on Weirs....29-30
Heads—Pressure in Pounds per Square Inch....271
Heating Pumping Station, by Electric Heat....126
Horsepower and Electrical Units....271
Horsepower, Computing from Revolving Watt-Hour Meters....192-193
Horsepower—Flow Powergraph....264
Horse Power, For Various Heads of Water....27
Horsepower, Head, Capacity and Efficiency Chart....261
Horse Power Table for Various Heads and Flows....260
Hydrant Maintenance....241-243 Mag. Sec.
Hydrants, Thawing, Rapid Emergency Method....65
Hydraulics, Practical....29
Hydraulic Pressure—Equivalents in Various Measures....27
Hydraulic Radius of Cast Iron Pipe—Table....69
Hydrogen Sulphide—Single Method for Determination....238
Hypochlorite Feeders, in Chlorinating Water Supply....163-165

I

Ice, Protecting A Reservoir Against....118
Imhoff Tanks....201
Incineration, Sludge—Modern Developments....247-248
Incrustation in Lime Solution Line, How to Retard Building up 214
Indicator, Corrosivity....160
Infiltration in Sewers—Proper Jointing to Prevent....180-181
Information on Water and Sewage Works Problems—A list of Representative Text Books, Handbooks, Journals, etc....17-18
Instruments (Indicating and Recording) For Main Line Meters..36-41
Iron and Hardness Removal....152-154
Iron, Forms of....157-158
Iron Removal—Small Systems....157-158

J

Jointing for Sewers....180-181
Joint Trunk Sewer, New Jersey—Maintenance Methods....172-174

K

Kennison Nozzle....37

L

Land Measure, Units and Diagram....275
Lime Solution Lines, How to Keep Clean....214
Literature on Water Works and Sewerage—A List of Representative Text Books, Handbooks, Journals, etc....17-18
Loss of Head—Through Pipe Lines of Various Sorts....21-22-23

M

Machines, for Chlorinating Water Supplies....163-165
Main Cleaning....77-79
Main Line Metering of Water, Sewage, Sludge....36-41
Main Line Metering with Propeller Type Meters....44-45
Mains, Cast Iron—Age Factor....46
Mains, Compressed Air Flushing of....80
Mains, Estimating Cost of....104-105
Mains, Water—Determining Condition of....67-69
Maintenance, Sewer—Copper Sulphate as an Aid to....197-198
Maintenance of Hydrants....241-243 Mag. Sec.
Maintenance of Large Meters in the Field....128-130
Maintenance of Sewers—Radio-Equipped Truck....172-174
Maintenance of Tanks and Standpipes....89-90
Maintenance of Waterworks Equipment....109-110
Maintenance, Water Meter....121-123
Materials, Weight of....277
Material Piles, Diagram for Contents....275
Mechanism of Corrosion of Water Pipes....133-138
Meter Checking—To Detect Water Waste....98-100
Meter Cradle....127
Meter Maintenance: Repair Shop Practices....109-110
Meter Reading....119-120
Meter Repair, a Small Shop for....124-126
Meters, Frequency of Testing....128-130
Meters, Large—Maintenance in the Field....128-130
Metering Modern Sewage Works....194-195
Metering: Practical Method of Procedure....119-120
Metering, Reasons for....119-120
Metering, Venturi Tubes....36-41
Metering: Water, Sewage and Sludge....36-41
Meters, Advantages of Outside Setting....119-120
Meters—Installation of Pipe Line....44-45
Meters—Location and Function in Activated Sluge Plant....194-195
Meters: Maintenance Practice....121-123

REFERENCE AND DATA INDEX

Water Works and Sewerage

1942

Meters—Propeller Type in Main Line....44-45
Meters, Revolving Watt-Hours, Computing Horsepower From..192-193
Meters, Venturi 20
Metric Measures and English Equivalents....277
Motors, Electrical 64-65
Multiple Health Type of Sludge Incineration....247-248

N

Nozzles and Offices in Main Line Metering.... 36
Nozzles—Flow Measuring 19
Nozzle Replacement on Trickling Filter....179

O

Odor Control, by use of Activated Carbon....148
Odors, Control in Sewers and Treatment Plants.....277-280 Mag. Sec.
Orders, Sewer—Traps for Manholes and Inlets....181
Operating Fundamentals of the Activated Sludge Process....206-209
Orifices and Nozzles in Main Line Metering.... 37
Orifices—In Flow Measurements....19-26
Orifice Method of Measuring Flows....267
Oxidization Lag—Cause of, in Sewage....206

P

Packing Pointers—Gate Valve and Hydrants.....238-240 Mag. Sec.
Packing Pointers—Ten Important Things Not to do....190
Paint—for Hydrants ....241-243 Mag Sec.
Painting Damp Water Pipes....130
Painting—Tanks and Standpipes....
Palmer Filter Bed Agitators....271-272 Mag. Sec.
Paving Breakers—Testing and Repairing....109-110
Piled Material—Diagram for Contents....275
Pipe, Brass and Copper, Delivery Capacity and pressure drop.262-263
Pipe Carrying Capacities, Relative....258
Pipe, Cast Iron—Dimension and Hydraulic Radius Values.... 69
Pipes, Comparative Carrying Capacities....276
Pipe, Concrete, Flow Computed by Manning Formula....268
Pipe, Concrete, Flow Diagram for Kutter's Formula....269
Pipe Fittings, Offset for 45 and 60 Degrees....262
Pipe, Flow Diagram....265
Pipe Handling and Transportation....106
Pipe Lines, Contents of....282-283 Mag. Sec.
Pipe Lines, Relative Carrying Capacities....258
Pipe Lines, Water Contained in....274
Pipe Runs, Diagram for Calculating Diagonal Lengths....278
Pipe Sweating—To Stop....104
Pipe, Transite—for Difficult Sewer Job....178-179
Pipes and Channels, Flow Measurement in....19-32
Pitometer Surveys—for Water Leakage, Waste, Stealing....98-100
Pilot Tube Measurements....25-28
Plumb-Bob Gage 31
Power Factor (Electrical)—Its Significance....61-62
Power—Lift Chart 270
Powers and Roots of Numbers, Diagram of....278
Power Water—Computation of Horsepower....27-28
Pressure in Pounds Per Square Inch—for Different Heads of Water 271
Pressure Relief Unit, in Gas System in Sewage Plant....217-226
Pressure Water—Equivalents in Various Measures.... 27
Pressure Water Table....260
Propeller Type Meters in Main Lines....44-45
Protecting a Reservoir Against Ice....118
Public Relations—Instructive Wall Panel at Aurora, Ill., Plant..241
Public Relations—Reminding Customer of High Cost of Water Through Leaks 113
Pump Pounding, Corrected by Simple "Air Sniffer".... 74
Pumping Cost, Chart for Determination....266
Pump Efficiency Comparison, Diagram....271
Pumping Sewage and Sludge....187-190
Pumping Station, Heating by Electric Heat....126
Pumping, Sludge 233-235
Pumping Terminology 54
Pumping Water—Gallons Delivered per KWH at Various Heads 52
Pump Tests for Efficiency.... 53
Pumps, Centrifugal—Basic Principles....51-54
Pumps, Centrifugal—Efficiency Checking....51-54
Pumps Centrifugal—Selection 51-54
Pumps, Reciprocating, Diagram of Capacity....274
Pumps, Types Used for Sludge Pumping....233-235
Purging Air Diffuser Plates with Chlorine....210

R

Radio Equipped Truck—for Sewer Maintenance....172-174
Rating and Sampling Wells by an **Improved Method**....117
Rating Wells—Method of....117
Red Water Prevention, With Calgon....269-270 Mag. Sec.
Relative Sizes of Branch and Water Main....106
Removal of Iron and Hardness....152-154
Renovating Water Meters....120
Reservoirs—Protecting Against Ice....118
Resistance of Valves and Fittings to Flow of Water....46-47
Resistance to Flow—By Pipes....21-22-23
Roots and Powers of Numbers, Diagram....278
Roots in Sewers—Killing with Copper Sulphate....198

S

Sampling of Wells, an Improved Method for....117
Sand Removal from Well Water....114-116
Scobey Formula and Chart....22-26-24
Screens—Trash and Sewage....202
Services, Corroded—Clearing with High Pressure Air.248-250 Mag. Sec.
Service Shooting with Compressed Air....248-250 Mag. Sec.
Sewage and Effluent Analyses....250-252
Sewage Gas Hazards—How to Eliminate at Plants....217-226
Sewage—Measurement in Modern Plants....194-195
Sewage Treatment at Appleton, Wisc....273-274 Mag. Sec.
Sewage Treatment—Copper Sulphate as an Aid to....197-198
Sewage Treatment Plant Operation....199-292
Sewage and Sludge Pumping....187-190
Sewage Screens—Design and Operation....199-202
Sewage Gas—Simple Method for Determining Hydrogen Sulphidem 238
Sewage Sludge—Value as Fertilizer....254-256
Sewage Treatment—Chlorine Dosage Controlling....211-214
Sewage Treatment Plants—Control of Odorous and Destructive Gases ....277-280 Mag. Sec.
Sewage Works—Method of Metering....194-195
Sewer Cleaning—Method on New Jersey Trunk Sewers....172-174
Sewer, Control of Odorous and Destructive Gases in.277-280 Mag. Sec.
Sewer Flushing Practices—Good and Indifferent....176-177
Sewer Jointing to Prevent Infiltration....180-181
Sewers, Killing Roots in, with Copper Sulphate....198
Sewer Maintenance—Copper Sulphate as an Aid to....197-198
Sewer Maintenance—Joint Trunk Sewer, New Jersey....172-174
Sewer Odor Traps for Manholes and Inlets....181

REFERENCE AND DATA INDEX

Water Works and Sewerage

1942

Sewer Pipe—Transite 178-179
Sewer Pipe, Vitrified, Diagram for Computing Discharge and Velocity of 193
Sewer Rents—Ohio Court Decision.....235
Sewer Rents and Water Service.....235
Sewer Rental, Bases for Service Charge.....169-171
Sewer Service and Maintenance.....172-174
Sewerage 169-252
Sheeting Method, in Difficult Sewer Job.....179
Slam, Check Valve—Elimination of.....58-59
Sludge, Air Dried, Preparation, Utilization and Sale of..... .....273-274 Mag. Sec.
Sludge and Sewage Pumping.....187-190
Sludge Bulking.....202, 203, 204
Sludge Concentration—Importance in Activated Sludge Process. 206-209
Sludge Gas—Engine Operation.....228-231
Sludge Gas Engine Installations in U.S.A......228-231
Sludge Incineration 247-248
Sludge Incineration—Modern Developments.....247-248
Sludge, Preparation and Utilization of.....273-274 Mag. Sec.
Sludge Pumping 233-235
Sludge Lines, Designs for Sludge Pumping.....233-235
"Sludge Triangle"—Use in Determining Sludge Solids.....236-238
Sludge Solids—Method of Determining.....236-238
Sludge Removal—Reducing Cost of.....240-241
Sludge—Value as Fertilizer.....254-256
Small Meter Shop.....124-126
"Sniffer" to Correct Pump Pounding..... 74
Softening Water—Removal of Iron and Hardness.....152-154
Solving Chlorine Ice Trouble 154
Square and Square Roots, Table of.....279
Storage, Elevated Tanks.....85-86
Standpipes, Maintenance of.....89-90
Standpipe and Tank Maintenance.....89-90
Storage, Elevated—Value of Elevated Tanks.....89-90
Stability Indicator 159-169
Steel Beams, Safe Load Diagram.....273
Strainer—for Removing Sand From Well Water.....114-116
Storing and Handling Ferric Chloride.....245-246
Surge in Pipe Lines—Correctives.....92-97
Surge Suppression—Devices for.....92-97
Surveys, Water Waste and Leakage.....98-100
Surface Wash—Economy of, in Filter Washing.....143-147
Surge Trouble in Pump Discharge Lines—Elimination of.....55-56

T

Tank and Standpipe Maintenance.....89-90
Tank Capacities 260
Tank, Elevated, as Settling Basin in Iron Removal.....157-158
Tanks, Elevated—Maintenance Value on Water Supply System...89-90
Tanks—Elevated Storage 85-86
Tanks, Horizontal or Vertical, Contents of.....282-283 Mag. Sec.
Taps—Table Showing Number for pipes for various sizes.....259
Taste and Odor Control, by use of Activated Carbon.....148
Terminology in Pumping..... 54
Thawing Hydrants—Rapid Emergency Method..... 65
Tractor—With Side Bins for Sludge Removal.....240-241
Transite Pipe in Difficult Sewer Job.....178-179
Transportation of Pipe and Materials.....106
Transportation Simplified 106
Traps, to Prevent Objectional Sewer Odors from Manholes.....181
Treatment of Water With Calgon.....269-270 Mag. Sec.
Treatment Plants, Control of Odorous and Destructive Gases in .....277-280 Mag. Sec.
Truck, Radio Equipped—for Sewer Service and Maintenance..172-174

U

Use of Water—"Where the Dollar Goes".....270

V

Vacuum Filter Dressing Rig.....242
Valves and Fitting—Diagram of Loss of Head..... 69
Valves and Fittings—Resistance to Flow.....46-47
Valve, Gate—Care and Maintenance.....238-240 Mag. Sec.
Velocity and Discharge, Diagram for Vitrified Clay Sewer Pipe...193
Velocity Control in Grit Chambers—Method of.....184-186
Venturi Meter Formulas..... 26
Venturi Tubes and Instruments in Metering.....36-41
Volume and Capacity Equivalents..... 28

W

Wall Panel, for Public Instruction at Sewage Treatment Plant....241
Washing, Filters, Observation on and Results with Methods, New and Old 143-147
Waste, Blotting Out.....113-123
Water and Sewer Accounts, Joint Administration and Collection of 169-171
Water Consumption—"Where the Dollar Goes".....270
Water Contained in Pipes, diagram for determining.....274
Water Delivered per K.W.H. of Pumping Power at Various Heads.. 52
Water Fixtures—Volume Demand and Rates of Flow for Various 112-113
Water—Flow, Friction, Measurement, Power.....19-32
Water Hammer, Cause of.....92-97
Water Hammer, Checking..... 59
Water Hammer Correctives.....92-97
Water Hammer—Eliminating Surge Troubles in Pump Discharge Lines 55-56
Water Hammer, Formulas for.....25
Water Main Branches—Relative Size of.....106
Water Main Cleaning.....77-79
Water—Main Line Metering.....36-41
Water Mains—Determining Condition of.....67-69
Water Meter Maintenance Practice.....121-123
Water Meters—Renovating of.....120
Water Pipes, Mechanism of Corrosion in.....133-138
Water Pipes, Painting Damp.....130
Water Power, Tables and Formulas.....27-28
Water Pressure Table Feet and Head.....260
Water Requirements for Various Uses and Fixtures.....112-113
Water Requirements—Volume Demand and Rates of Flow for Various Uses and Fixtures.....112-113
Water Service and Sewer Rents.....235
Water Service and Sewer Rents—Ohio Court Decision on.....235
Water Supply—Elevated Storage Values.....85-86
Water Theft—Detection by Observing Sewer Flow.....101
Water Treatment with Calgon.....269-270 Mag. Sec.
Water Waste Detection by Observing Sewer Flows.....101
Water Waste Surveys and Leak Correction.....98-100
Watt-Hour Meters, Computing Horsepower from.....192-193
Weights and Measures, general tables.....277
Weights of Materials.....277
Weirs, Construction and Use..... 29
Weirs—Formulas and Discharge Table..... 29
Wells, Drilling and Developing in Rock.....251-252 Mag. Sec.
Well Water—Sand Removal from.....114-116
Wooden Beams—Safe load diagram.....272

IN THE 1941 ISSUE

Below is an index to reference and data material which may be found in our last year's (1941) issue. The items here listed are NOT to be found in this year's issue.

This listing together with the 1942 Index, gives what amounts to a "Consolidated Index" for two consecutive annual issues. The practice is to be continued henceforth as an additional aid to those who find the reference and data sections useful.

A

Activated Sludge Blanket Detector....230
Activated Sludge Bulking—Causes and Corrective Measures...226-229
Air Diffusers, Servicing of Porous Plates & Tubes....231-233
Algae Control....102, 103
Alkalinity—Diagram of pH and CO_2 Relations....256
Ammonia—Advantages of Aqua Ammoniation....95-96
Ammonia, Anhydrous: Storage & Handling....117-121
Area Calculation of Various Shapes....269-271

B

Bells, Pump Suction—Submergence and Spacing of.... 25
Bending Pipes—A Kink....155
Biofiltration System....189-195
Blowing Out Service Lines—for Better Flow.... 80
Bushings—Made from Standard Pipe....240

C

Cable—How to Estimate Length in Coil or Roll....267
Carbon Dioxide—Diagram of pH and Alkalinity Relations....256
Carbon Feed Record in Filters.... 91
Cathodic Protection of Sludge Digester Parts....211-215
Cathodic Protection for Tanks and Submerged Metallic Parts....51-52
Centrifugal Pumps—Specific Speed Curves.... 22
Centrifuge—In Rapid Sludge Solids Estimations....222-224
Channels, Rectangular and Circular—Diagrams for Flow....252-253
Check Valves—For Surge Control....38-41
Chlorine Ice Troubles, Solution for....121
Chlorine: Properties of, Storage and Handling....124-127
Chlorine Treatment for Algae....102, 103
Compressed Air, Dewatering Mains with.... 82
Conduits—Diagrams for Rates of Flow....252-253
Concrete Proportioning Table....266
Cooling Water—With Underground Coils.... 41
Copper—Its Effect on Health....103
Copper Sulphate—Killing Roots in Sewers....140
Copper Sulphate: Uses and Methods of Application....105-107
Copper Sulphate Treatment for Algae....102, 103
Cylinder Handling Carriage (Cl, NH_3, SO_2)....127

D

Degreasing Sewage and Industrial Wastes—by Aero-Chlorination....197-202
Dewatering Mains with Compressed Air.... 82
Diffusers (Plates and Tubes), Servicing of....231-233
Diffuser Plate Purging—with Chlorine Gas....234
Digester Corrosion—and Cathodic Protection....211-215

E

Electrical Pipe Thawing....70-72
Elutriation of Sludges—Equipment and Experiences....182-184
Engine Operation on Sludge Gas....203-206
Expansion Chart for Piping, Rods, etc....265

F

Filter Bed Maintenance....91-93
Filter Bed Maintenance—Mud Ball and Hard Spot Breaker.... 96
Filter Nozzle Replacement....168
Filter Washing with Porous Bottoms....99-101
Financing Sewerage—Methods and Experience....129-131
Fire Flows—Underwriters' Requirements.... 68
Fire Hydrant Discharge Measurement....65-66
Fire Protection, Water Supply in....42-43
Flammability of Gas-Air Mixtures....210
Flow Through Conduits—Simplified Formulae for....159
Flow—Diagram for Loss of Head in Pipes....246
Flow Gage for Channels, Conduits, Sewers....166
Flow—Pipe Line Coefficients....59-61
Flow—Pipe Flow Diagram....251
Flow in Rectangular and Circular Channels—Diagrams....252-253
Flow in Sewers—Formulae Approximating Kutter's....159
Flushing Sewers—Some Notes on.... .135, 136
Freezing, Protecting Pipes Against.... 74

G

Gas Hazards—Reducing at Sewage Plants....208-210
Grease Removal—Aero Chlorination....197-202
Grit Collection and Washing....144-159

H

Handling and Transporting Pipes and Materials.... 79
Hard Water: Methods of Softening....110-113
Head—Diagram for Loss in Pipes....246
Hydrant Discharge Measurements....65-66

I

Imhoff Tanks....176
Industrial Waste Treatment—on High Rate: High Capacity Filters....189-195

J

Jigging Grit....156-159

K

Kutter's Formula Simplified for Sewers and Drains....159

L

Laboratory Apparatus and Equipment for Sewage Plants....220-221
Leak Cost Chart.... 79
Leakage Detection (Surveys)—on Mains and Services....89-90
Leveling and Aligning by Simple Methods....265
Lime and Lime Slaking....115-116
Lime Feeding Device.... 93

M

Mains—Dewatering with Compressed Air.... 82
Mains—Feeding Lime Solution Into.... 93
Main Tapping—Improved Methods of Making.... 82
Maintenance of Sewage Pumping Stations....169-171
Maintenance of Sewers—Practices....132-137
Mapping Sewers....132-136
Mensuration....269-271
Mercury and Water Equivalents in Ozs....266
Meter Renovating.... 85
Meter Testing....86-87
Meterization—Selecting the Right Meter....84-85
Mud-Ball and Hard-Spot Breaker.... 96

N

Nozzle Replacement on Trickling Filters....168

P

pH Conversion—Diagram of Alkalinity and CO_2 Relations....256
pH Zones in Water Supply and Sewage Treatment....257
Pipe and Tank Contents....263
Pipes—Diagrams for Loss of Head....246
Pipe Flow Diagram....251
Pipe Handling and Transportation.... 79
Pipe—Protection from Freezing.... 74
Pipes—Thawing Electrically....70-72
Pitometer Surveys—For Water Leakage, Waste, Stealing....89-90
Power and Heat Equivalents....266
Pumping Station—Maintenance....169-171
Pumps, Centrifugal—Specific Speed Curves.... 22
Purging Air Diffuser Plates, with Chlorine....234

R

Relief Valves—For Surge and Water Hammer....38-41
Root Cuttings in Sewers....141
Roots in Sewers—Their Elimination....136-138

S

Safety Equipment for Sewage Plants....209
Screenings, Trituration of and Return to Sewage....143
Screens—Trash and Sewage....175
Sewage, Degreasing....197-202
Sewage Filtration, Biofiltration System....189-195
Sewerage Financing—Methods and Experience....129-131
Sewage Gas Flammability....210
Sewage Grit-Collection, Washing and Disposal....144-159
Sewage Pumping Station Maintenance....169-171
Sewage Treatment—Apparatus for Collecting Flocced Samples....101
Sewage Treatment—Hourly Load Variations and Plants....185-186
Sewage Treatment—pH Zones of Import....257
Sewage Plant Laboratory Equipment....216-221
Sewage Treatment Processes—Various....173-174
Sewer Cleaning....141, 142
Sewer Cleaning Equipment—Some Notes on....132
Sewer Cleaning with Rubber Beach Balls....168
Sewer Flow—Diagrams for Rates of Flow in Circular and Rectangular Channels....252-253
Sewer Flow—Simplified Formulae for Determining....159
Sewer "Hoe" for Cleaning....141
Sewer Maintenance, Practices....132-138
Sewer Rentals and Collection Practices....129-131
Sewers—Size and Slope—Determined by Simple Formulae....159
Sewerage Operating Kinks....141, 142
Shaft Aligning by Simple Method....265
Slide Rule for Sewage Operators....131
Sludge Blanket Detector and Turbidimeter for Activated Sludge..230
Sludge Bulking—Causes and Correction....226-239
Sludge Bulking Control—in Activated Process....178
Sludge Concentration (Thickening)—Importance of....224
Sludge Digester Corrosion—and Cathodic Protection....211-215
Sludge Disposal—Aided by Elutriation....181-184
Sludge Elutriation Equipment and Experience....182-184
Sludge Solids Estimated Rapidly by Centrifuging....222-224
Sludge Volume Reductions—Importance to Plant Operation..224-225
Softening Water: Economic Aspects of....110-113
Suction Bells, Submerged and Spacing of.... 25
Sulphide Determination by Simple Method....225
Surge in Pipe Lines—Its Study and Correction....38-41

T

Tanks—Cathodic Protection against Corrosion....51-52
Tank and Pipe Contents....263
Taps (Large Size)—Improved Method of Making.... 82
Temperature Expansion Diagram for Piping, Rods, etc....265
Testing Water Meters....86-87
Theft of Water—Methods of Detection....89-90
Thawing Pipes Electrically....70-72
Trade Waste Treatment—High Capacity Trickling Filters....189-195
Trickling Filter Systems—High Capacity Type....189-195
Trigonometric Calculations Made Simple....269-271
Trituration of Sewage Screenings—Operating Experience & Costs..143
Turbidimeter and Sludge Blanket Detector....230

U

Underwriters' Requirements for Fire Flow.... 68

V

Volume Calculation for Various Solids....269-271

W

Water and Mercury Equivalents of Ozs....266
Water and Sewage Pumping—Submergence and Spacing of Suction Bells.... 25
Water Cooling with Underground Coils.... 41
Water Flow—Diagram for Loss of Head in Pipes....246
Water Flow—Diagrams for Rectangular and Circular Channels.252-253
Water Flow—Pipe Line Coefficients....59-61
Water Hammer (Surge)—Its Study and Correction....38-41
Water Treatment—Apparatus for Collecting Flocculated Samples..101
Water Treatment—Aqua Ammoniation....95-96
Water Treatment—Device for Feeding Lime Solution.... 93
Water Treatment—Lime and Lime Slaking....115-116
Water Treatment—Methods and Economic Aspects of Softening.110-113
Water Treatment—pH Zones of Import....257
Water Waste Surveys—Instruments and Methods Employed in..89-90
Welding Units and Electrical Thawing.... 70
Wire—Standard Gauges....262

CLASSIFIED INDEX of PRODUCTS

Although this index is not published as a COMPLETE index of all materials and equipment used in the Water Works and Sewerage fields—it really is a very comprehensive list of products. It includes equipment and materials produced or marketed in this field by 196 manufacturers who have used WATER WORKS & SEWERAGE in advertising such products during 1941 and 1942. Of these 196 manufacturers you will find the advertisements of 154 in this issue.

ABRASIVES
Carborundum Co., Niagara Falls, N. Y.

ACID, SULPHURIC AND HYDROCHLORIC
General Chemical Co., 40 Rector St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ACTIVATED AND BLACK ALUM
Activated Alum Corp., Curtis Bay, Baltimore, Md.

ACTIVATED CARBON
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Darco Corporation, 60 E. 42nd St., New York City.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Industrial Chemical Sales Division, West Virginia Pulp & Paper Co., 230 Park Ave., New York City.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
L. A. Salomon & Bro., 216 Pearl St., New York City.

ACTIVATED SLUDGE EQUIPMENT
The American Well Works, Aurora, Illinois.
Carborundum Co., Niagara Falls, N. Y.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago,, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Vogt Mfg. Co., Louisville, Ky.

AERATION APPARATUS
Aluminum Co. of Amer., Gulf Bldg., Pittsburgh, Pa.
The American Well Works, Aurora, Ill.
Carborundum Co., Niagara Falls, N. Y.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas Ciy, Mo.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

AGITATORS
Activated Alum Corp., Curtis Bay, Baltimore, Md.
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., Inc., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Mach. Co., Inc., 3409 E. 18th, Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.

AIR BLOWERS
(See Blowers, Air)

AIR COMPRESSORS
(See Compressors, Air)

ALLOY CAST IRON PIPE AND FITTINGS
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

ALTERNATORS, ELECTRIC
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Clark Controller Co., 1146 E. 152nd St., Cleveland, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Innis, Speiden & Co., 117 Liberty St., New York City.

ALUM, AMMONIA
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ALUM, BLACK
Activated Alum Corp., Curtis Bay, Baltimore, Md.

ALUM (FILTER), COMMERCIAL, IRON-FREE
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

AMMONIA, ANHYDROUS & AQUA
General Chemical Co., 40 Rector St., New York City.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Mathieson Alkali Wks., Inc., 60 E. 42nd St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

AMMONIATORS
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Omega Mach. Co., Inc., 3409 E. 18th, Kansas City, Mo.
Proportioneers, Inc., 9 Codding St., Providence, R. I. (Aqua)
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

ANALYTICAL WARE
Carborundum Co., Niagara Falls, N. Y.
Chemlab Specialties Co., 52 Alvarado Road, Berkeley, Calif.
Phipps & Bird, Inc., Richmond, Va.

ANEMOMETERS
M. C. Stewart, Ashburnham, Mass.

ANTHRAFILT
Anthracite Equipment Corp., 19 Rector St., New York City.

AQUA AMMONIATORS
(See Ammoniators)

AQUAPHONES
Aqua Survey & Instrument Co., 1409 Marlowe Ave., Cincinnati, Ohio.
Northrop & Co., Inc., 50 Church St., N. Y., N. Y.

ASBESTOS-CEMENT PIPE
Johns-Manville Co., 22 E. 40th St., New York City.

ASH AND COAL HANDLING MACHINERY
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

AUTOMATIC FILTER AND SOFTENER CONTROLS
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., Philadelphia, Pa.

BACK FILLERS
Link-Belt Speeder Corp., 301 W. Pershing Rd., Chicago, Ill.

BAR SCREENS
The American Well Works, Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

BASE-EXCHANGE SILICATE
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th. Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

BASIN CLEANERS
Champion Corp., Hammond, Ind.
W. H. Stewart, P. O. 767, Syracuse, N. Y.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

BEARINGS, ROLLER & BALL
Chain Belt Co., Milwaukee, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 519 N. Holmes Ave., Indianapolis, Ind.

BINS, STORAGE
Chain Belt Co., Milwaukee, Wis.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Portland Cement Association, 33 W. Grand Ave., Chicago, Ill.

BITUMINOUS COATINGS AND LININGS
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Quigley Co., Inc., 56 W. 45th St., New York City.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Wailes Dove-Hermiston Corp., Westfield, N. J.

BLACK ALUM
Activated Alum Corp., Curtis Bay, Baltimore, Md.

BLEACHING POWDER
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

BLOWERS, AIR
De Laval Steam Turbine Co., Trenton, N. J.
Roots-Connersville Blower Corp., Connersville, Ind.

BLOWERS (GASOLINE) ENGINE DRIVEN (PORTABLE)
Homelite Corporation, Port Chester, N. Y.

BOILER BLOWOFF APPARATUS
Permutit Co., 330 W. 42nd St., New York City.

BOILER FEED PUMP CONTROL
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

BOILER FEEDWATER TREATMENT
The American Well Works, Aurora, Ill.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Buromin Co., 300 Ross St., Pittsburgh, Pa.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.

Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hall Laboratories, Inc., Hagan Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Penn.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.
Worthington Pump & Machinery Corp., Harrison, New Jersey.
Zeolite Chemical Co., 140 Cedar St., New York City.

BOILER FURNACE, BRICK
Carborundum Co., Niagara Falls, N. Y.
Quigley Co., Inc., 56 W. 45th St., New York City.

BOILER PLANT ACCESSORIES
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

BOILERS, GAS
American Radiator & Standard Sanitary Corp., Bessemer Bldg., Pittsburgh, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

BOILER WATER PURIFICATION APPARATUS
The American Well Works, Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Corp., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 301 W. Pershing Rd., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 3409 E. 18th. Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.
Worthington Pump & Machinery Corp., Harrison, New Jersey.

BOXES, VALVES AND METERS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

BRAKES, MAGNETIC, MECHANICAL, HYDRAULIC
The Clark Controller Co., 1146 East 152nd St., Cleveland, Ohio.

BRASS GOODS
(See also Pipe, Brass.)
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

BREECHINGS, STEEL
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

BUCKETS, SEWER
Champion Corp., Hammond, Ind.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

BUFFER SOLUTIONS & MIXTURES
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.

CALCIUM HYPOCHLORITE
Innis, Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

CALGON (See Corrosion Suppression and Water Stabilization)

CALKING MACHINES & TOOLS
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
Schramm, Inc., West Chester, Pa.

CARBON-ACTIVATED
(See Activated Carbon.)

CARBONATORS (Recarbonation).
Carborundum Co., Niagara Falls, N. Y.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

CAR SPOTTERS & HAULAGE SYSTEMS
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2410 W. 18th St., Chicago, Ill.

CASTINGS, IRON, STEEL, ALLOY STEEL, ETC.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Chain Belt Co., Milwaukee, Wis.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
M & H Valve & Fittings Co., Anniston, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

CAST IRON PIPE
(See Pipe.)

CATCH BASIN INLET
Northrop & Co., Inc., 50 Church St., New York City.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.

CATCH BASINS, CORRUGATED IRON
Armco Drainage Products Assn., Middletown, Ohio.

CATHODIC PROTECTIVE PROCESS
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio.
Rusta Restor Corp., 1480 W. State St., Fremont, Ohio.

CAULKING
Standard Dry Wall Products, Inc., New Eagle, Pa.

CAUSTIC SODA
Diamond Alkali Co., Pittsburgh, Pa
Dow Chemical Co., Midland, Mich
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
Solvay Sales Corp., 40 Rector St., New York City.

CEMENT
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

CEMENT, ASBESTOS PIPE
Johns-Manville, 22 E. 40th St., New York City.

CEMENT PIPE
(See Pipe, Cement; Pipe, Concrete.)

CEMENT LINED PIPE
(See Pipe.)

CEMENTS, ACID PROOF
Atlas Mineral Prod. Co., Mertztown, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Quigley Co., Inc., 56 W. 45th St., New York City.

CEMENTS, REFRACTORY
Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.
Quigley Co., Inc., 56 W. 45th St., New York City.

CEMENTS, SEWER PIPE
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Quigley Co., Inc., 56 W. 45th St., New York City.

CEMENTS, WATER MAINS
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Girard Trust Bldg., Philadelphia, Pa.

CHAINS (Elevating, Conveying & Power Transmission)
Chain Belt Co., Milwaukee, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

CHEMICAL CONVEYING EQUIPMENT
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

CHEMICAL FEEDING & PROPORTIONING EQUIPMENT
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 3409 E. 18th, Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeder, Inc., 110 Washington St., Buffalo, N. Y.

CHEMICALS FOR WATER PURIFICATION
Activated Alum Corp., Curtis Bay Baltimore, Md.
Ansul Chemical Co., P. O. Box 231, Marinette, Wis.
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Darco Corp., 60 E. 42nd St., New York City.
Diamond Alkali Co., Pittsburgh, Pa
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Industrial Chemical Sales Div West Virginia Pulp & Paper Co., 230 Park Ave., New York.
Innis-Speiden & Co., 117 Liberty St., New York City.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Mathieson Alkali Works, Inc., 60 E. 42nd St., New York.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
National Lime Assn., 927 Fifteenth St. N. W. Washington, D. C.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Reilly Tar & Chem. Co., Merchants Bank Bldg., Indianapolis, Ind.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Solvay Sales Corp., 40 Rector St., New York.
Standard Silicate Div., Diamond Alkali Co., Pittsburgh, Pa.
Tamms Silica Co., 228 N. LaSalle St., Chicago, Ill.
Virginia Smelting Co., West Norfolk, Va.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

CHEMISTS AND ENGINEERS
(See Directory of Experts, pages 108-109)

CHLORIDE, FERRIC
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Innis-Speiden & Co., 117 Liberty St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

CHLORIDE OF LIME (CHLORINATED LIME)
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.

CHLORINATORS
(See also Hypochlorinators.)
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

CHLORINE, LIQUID
Diamond Alkali Co., Pittsburgh, Pa.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
Solvay Sales Corp., 40 Rector St., New York.
Wallace & Tiernan, Inc., Newark, N. J.

CHLORINE CONTROL EQUIPMENT
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

CHUTES, COAL, ETC.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Jeffrey Mfg. Co., Columbus, Ohio.
Link Belt Co., 300 W. Pershing Rd., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

CLAMPS AND SLEEVES, PIPE
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Carson-Cadillac Corp., Birmingham, Ala.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

CLAMPS, BELL JOINT
Carson-Cadillac Corp., Birmingham, Ala.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

CLAMPS, PIPE REPAIR
Carson-Cadillac Corp., Birmingham, Ala.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Northrop & Co., Inc., 50 Church St., New York City.

CLARIFIERS, SEWERAGE AND WATER
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

CLEANING SEWER MAINS
Champion Corp., Hammond, Ind.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

CLEANING WATER MAINS
National Water Main Cleaning Co., 50 Church St., New York City.

COAGULANTS & COAGULATION CONTROL CHEMICALS
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Innis-Speiden & Co., 117 Liberty St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Permuitit Co., 330 W. 42nd St., New York City.
Philadelphia Quartz Co., 124 S. Third St., Philadelphia, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.

COAL & ASHES HANDLING MACHINERY
(See Ash & Coal Handling Machy.)

COATINGS, ACID & ALKALI-PROOF FOR CONCRETE, STEEL AND WOOD
Atlas Mineral Products Co., Mertztown, Pa.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Philadelphia Quartz Co., Philadelphia, Pa.
Quigley Co., Inc., 56 W. 45th St., New York City.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Wailes Dove-Hermiston Corp., Westfield, N. J.

COATINGS AND LININGS
(See Bituminous Coatings and Linings.)

COCKS, CURB, METER, CORPORATION, ETC.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

COLLECTORS (SLUDGE)
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.

COMBUSTION INDICATORS AND RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Permutit Co., 330 W. 42nd St., New York City.

COMMINUTORS
The American Well Works, Aurora, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

COMPARATORS (COLOR)
Hellige, Inc., 3718 Northern Bldg., Long Island City, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

COMPOUNDS, COUPLING
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.

COMPOUNDS, SEWER JOINT
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Quigley Co., Inc., 56 W. 45th St., New York City.
Reilly Tar & Chem. Co., Merchants Bank Bldg., Indianapolis, Ind.

COMPRESSORS, AIR
De Laval Steam Turbine Co., Trenton, N. J.
Gardner-Denver Co., Quincy, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Roots-Connersville Blower Corp., Connersville, Ind.
Schramm, Inc., West Chester, Pa.
Worthington Pump & Machinery Corp., Harrison, New Jersey.

CONCRETE
Portland Cement Association, 33 W. Grand Ave., Chicago, Ill.

CONCRETE BREAKERS
Schramm, Inc., West Chester, Pa.

CONCRETE HARDENER
Connelly Iron Sponge and Governor Co., 3154 So. California Ave. Chicago, Ill.
Diamond Alkali Co., Pittsburgh, Pa.
Philadelphia Quartz Co., 124 S. Third St., Philadelphia, Pa.
Standard Silicate Div., Diamond Alkali Co., Pittsburgh, Pa.

CONCRETE MIXERS
Chain Belt Co., Milwaukee, Wis.

CONCRETE PIPE
(See Pipe, Concrete.)

CONDENSERS (STEAM)
Amer. Cast Iron Pipe Co., Birmingham, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
Worthington Pump & Machy. Corp., Harrison, N. J.

CONTROLLERS, AUTOMATIC, ELECTRIC
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

CONTROLLERS, FLOW, LEVEL, PRESSURE, TEMPERATURE
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.

CONVEYORS AND CONVEYING EQUIPMENT
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Mfg. Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Merrick Scale Mfg. Co., 180 Autumn St., Passaic, N. J.

COOLING TOWERS
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.

COPPER, BRASS, BRONZE
American Brass Co., Waterbury, Conn.
Mueller Brass Co., Port Huron, Mich.

COPPERAS
Innis-Speiden & Co., 117 Liberty St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.

COPPER SULPHATE
General Chemical Co., 40 Rector St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.

COPPER TUBE, FLEXIBLE
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.

CORROSION SUPPRESSION
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio.
Rusta Restor Corp., 1480 W. State St., Fremont, Ohio.

COUPLINGS & CONNECTIONS, PIPE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
National Tube Co., Frick Bldg., Pittsburgh, Pa.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

COUPLINGS, FLEXIBLE
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Chain Belt Co., Milwaukee, Wis.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Dresser Mfg. Co., Bradford, Pa.
Jeffrey Mfg. Co., Columbus, Ohio.
Link Belt Co., 220 S. Belmont Ave., Indianapolis, Ind.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

COVERS, HANDHOLE, MANHOLE, SAMPLING
Northrop & Co., Inc., 50 Church St., New York City.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

CRANES & HOISTS
Link-Belt Speeder Corp., 301 W. Pershing Rd., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.

CULVERT CLEANERS
Champion Corp., Hammond, Ind.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.

CULVERTS
American Cast Iron Pipe Co., Birmingham, Ala.
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Clow and Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City (Asbestos-Cement).
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J. (Cast Iron)
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., Philadelphia, Pa.

CURB BOXES
Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.

DECHLORINATING EQUIPMENT AND CHEMICALS
Ansul Chemical Co., P. O. Box 231, Marinette, Wis.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco., Inc., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Virginia Smelting Co., 131 State St., Boston, Mass.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

DEMOLITION TOOLS
Schramm, Inc., West Chester, Pa.

DIAPHRAGM, PUMP
Ralph B. Carter Co., 53 Park Pl., New York City.
Dorr Co., 570 Lexington Ave., New York City.
Edson Corp., 49 D St., South Boston, Mass.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

DIFFUSERS—PLATES & TUBES
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

DIGESTERS EQUIPMENT (SLUDGE)
Ralph B. Carter Co., 53 Park Pl., New York City.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

DISTRIBUTORS (FILTER)
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

DRAINS, STORM
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., Philadelphia, Pa.

DRIVES, CHAIN
Chain Belt Co., Milwaukee, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

DRY CHEMICAL FEEDERS
(See Chemical Feeding Equipment)

DRYERS, ROTARY
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

ELECTRICALLY OPERATED GATE VALVES
Crane Co., 836 S. Michigan Ave., Chicago.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

ELEVATING AND CONVEYING EQUIPMENT
(See Conveyors & Conveying Equipment.)

ENGINEERS AND CHEMISTS
(See Directory of Experts, pages 108-109.)

ENGINES, DIESEL
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Schramm, Inc., West Chester, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

ENGINES, SEWAGE SLUDGE GAS
Worthington Pump & Machy. Corp., Harrison, N. J.

EXPANSION JOINTS—PIPE
(See Joints—Expansion, Pipe)

FEED, CHEMICAL
(See Chemical Feeding Equipment.)

FEED WATER FILTERS
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Worthington Pump & Machinery Corp., Harrison, N. J.

FEED WATER HEATERS
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Permutit Co., 330 W. 42nd St., New York City.
Worthington Pump & Machy. Corp., Harrison, N. J.

FEED WATER TREATMENT
(See Boiler Feed Water Treatment)

FERRIC CHLORIDE, LIQUID & ANHYDROUS
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich. (Liquid & 60% crystal)
General Chemical Co., 40 Rector St., New York City.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Innis, Speiden & Co., 117 Liberty St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa. (Liquid)
Wallace & Tiernan Co., Inc., Newark, N. J.

FERRIC CHLORIDE FEEDERS
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Omega Machine Co., Inc., 3409 E. 18th, Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

FERRIC SULFATE
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga., & Lockland, O.

FERROUS SULPHATE
General Chemical Co., 40 Rector St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.

FILTER-AIDS
Johns-Manville, 22 E. 40th St., New York City. (Celite.)
L. A. Salomon & Bro., 216 Pearl St., New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

FILTER CLEANING PROCESS
Roberts Filter Mfg. Co., Darby, Pa.
Virginia Smelting Co., West Norfolk, Va.

FILTER CLOTHS
(Cotton, Wool & Jute)
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

FILTERING EQUIPMENT
The American Well Works, Aurora, Ill.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chain Belt Co., Milwaukee, Wis.
R. D. Cole Mfg. Co., Newnan, Ga.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Laughlin Equipment Corp., 270 Madison Ave., New York City.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Underpinning & Foundation Co., Inc., 155 E. 44th St., New York City (For Sewage)
Worthington Pump & Machinery Corp., Harrison, N. J.

FILTER PLATES AND TUBES
Carborundum Co., Niagara Falls, N. Y.

FILTER RATE CONTROLLERS & GAGES
(See Rate Controllers.)

FILTER & WATER SOFTENING PLANTS (COMPLETE)
Chain Belt Co., Milwaukee, Wis.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Laughlin Equipment Corp., 270 Madison Ave., New York City.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Neville Island P. O., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Worthington Pump & Machinery Corp., Harrison, N. J.
Zeolite Chemical Co., 140 Cedar St., New York City.

FILTER UNDERDRAINS (PIPE & PLATES)
Armco Drainage Products Assn., Middletown, Ohio.
Carborundum Co., Niagara Falls, N. Y.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

FILTER WASH CONTROL
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

FILTER SAND
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Laughlin Equipment Corp., 270 Madison Ave., New York City.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Zeolite Chemical Co., 140 Cedar St., New York City.

FITTINGS, PIPE, SOLDER TYPE
American Brass Co., Waterbury, Conn.
American Smelting and Refining Co., 120 Broadway, N. Y. C.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Brass Co., Port Huron, Mich.

FITTINGS, TEES, ELLS, ETC.
American Brass Co., Waterbury, Conn.
American Cast Iron Pipe Co., Birmingham, Ala.
American Smelting and Refining Co., 120 Broadway, N. Y. C.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Carson-Cadillac Corp., Birmingham, Ala.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

FLASH MIXING EQUIPMENT
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.

FLEXIBLE JOINTS
(See Joints, Flexible Pipe.)

FLOATING COVERS
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

FLOCCULATING EQUIPMENT
The American Well Works, Aurora, Ill.
Carborundum Co., Niagara Falls, N. Y.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

FLOOR STANDS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa (Manually and Electrically Operated)
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1539 N. Sheffield Ave., Chicago, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

FLOW METERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Northrop & Co., Inc., 50 Church St., New York City.
Roots-Connersville Blower Corp., Connersville, Ind.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

FLOW RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

FLOW REGULATORS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

FLUMES, IRON & STEEL
Armco Drainage Products Assn., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

FOOT VALVE WITH STRAINER
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Edson Corp., 49 D St., So. Boston, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

FORMS & GASKETS FOR PIPE JOINTS
Johns-Manville, 22 E. 40th St., New York City.
L. A. Weston, Adams, Mass.

FURNACES, MELTING, POURING LADLES, POTS, ETC.
Atlas Mineral Products Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.

GARBAGE DISPOSAL APPARATUS
Carborundum Co., Perth Amboy, N. J.
Chain Belt Co., Milwaukee, Wis.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Nichols Engr. & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Underpinning & Foundation Co., 155 E. 44th St., New York City.

GAS DIFFUSERS
Carborundum Co., Niagara Falls, N. Y.
Dorr Co., 570 Lexington Ave., New York City.
Vogt Mfg. Co., Louisville, Ky.

GAS HOLDERS
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.

Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

GAS PUMPS
(See Pumps, Gas)

GAS PURIFICATION
Connelly Iron Sponge and Governor Co., 3154 So. California Ave., Chicago, Ill.

GAS REGULATORS
(Pressure & Flow)
(See Regulators—Water & Gas)

GATES, SHEAR
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

GATES, SLUICE
Armco Drainage Products Assn., Middletown, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.

GATE VALVE HOUSING
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.

GATE VALVES
(See Valves, Gate.)

GAUGES (Liquid Level, Pressure Recording)
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City (Pressure)
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.

GEARS, SPEED REDUCING
De Laval Steam Turbine Co., Trenton, N. J.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

GENERATORS, SETS, ELECTRIC & DIESEL ENGINES
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Homelite Corp., Port Chester, N. Y. (Gasoline Engine Driven and Portable.)
Northrop & Co., Inc., 50 Church St., New York City (Gasoline Driven Portable)
Worthington Pump & Machy. Corp., Harrison, N. J.

GOOSENECKS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.

GREEN SAND (Zeolite)
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Zeolite Chemical Co., 140 Cedar St., New York City.

GRINDERS
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.

GRIT CHAMBER EQUIPMENT
The American Well Works, Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

HAMMERS, REPLACEABLE FACE
Greene, Tweed & Co., Bronx Blvd. at 238th St., New York City.

HOSE, STEAM, AIR, WATER, SUCTION
American Brass Co., Waterbury, Conn.
Edson Corp., 49 D St., So. Boston, Mass.
Gardner-Denver Co., Quincy, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Schramm, Inc., West Chester, Pa.

HYDRANT PUMPS
(See Pumps, Hydrant.)

HYDRANTS (FIRE)
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Decatur, Ill.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

HYDRAULICALLY OPERATED GATE VALVES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

HYDROGEN ION EQUIPMENT
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Permutit Co., 330 W. 42nd St., New York City.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

HYPO-CHLORINATORS
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

HYPOCHLORITES (High Test)
(See Calcium Hypochlorite)

INCINERATORS
Dorr Co., Inc., 570 Lexington Ave., New York City.
Nichols Engr. & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Underpinning & Foundation Co., 155 E. 44th St., New York City.

INDICATOR POSTS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

INDICATORS, LARGE DIAL, ILLUMINATED
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, O.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

INSULATION
Carborundum Co., Perth Amboy, N. J.
Ford Meter Box Co., Wabash, Ind. (Water Meter).
Johns-Manville, 22 E. 40th St., New York City.
Quigley Co., Inc., 56 W. 45th St., New York City.

IRON SULPHATE
Innis, Speiden & Co., 117 Liberty St., New York City.

JOINTING COMPOUND
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Quigley Co., Inc., 56 W. 45th St., New York City.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.

JOINTS, EXPANSION—PIPE
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Lock Joint Pipe Co., Ampere, N. J.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

JOINTS, FILLER
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.

JOINTS, FLEXIBLE PIPE
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Lock Joint Pipe Co., Ampere, N. J.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

JOINTS, MECHANICAL (FLEXIBLE)
American Cast Iron Pipe Co., Birmingham, Ala.
Carson-Cadillac Corp., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
Weston's Gaskets & Forms, Adams, Mass.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

JOINTS, RUBBER RING
Ralph H. Hyde, Box 1, Campbell, Calif.
Water & Sewer Equip. Co., Rome, N. Y.

JUTE, BRAIDED AND TWISTED
Atlas Mineral Prod. Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hydraulic Development Corp., 50 Church St., New York City.
Johns-Manville, 22 E. 40th St., New York City.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.

LABORATORY APPARATUS
Carborundum Co., Niagara Falls, N. Y.
Chemlab Specialties Co., 52 Alvarado Road, Berkeley, Calif.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
E. Leitz, 730 Fifth Ave., New York City.
Omega Mach. Co., Inc., 3409 E. 18th, Kansas City, Mo.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

LEAK LOCATING INSTRUMENTS
(See Water Leak Locating Instruments)

LIQUID CHLORINE
(See Chlorine, Liquid.)

LIME
National Lime Assn., 927 Fifteenth St. N. W. Washington, D. C.

LUBRICATING OILS & GREASES
Macmillan Petroleum Corp., 530 W. Sixth St., Los Angeles, Calif.

MANHOLE CUSHIONS (anti-Rattle)
Tapax Mfg. Co., Mamaroneck, N. Y.
Turbine Sewer Machine Co., Inc., 5210 W. State St., Milwaukee, Wis.

MANOMETERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Connelly Iron Sponge and Governor Co., 3154 S. California Ave., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

METER ACCESSORIES, BOXES, HOUSING, ETC.
Badger Meter Co., Milwaukee, Wis.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METER COUPLINGS & YOKES
Badger Meter Mfg. Co., Milwaukee, Wis.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
Neptune Meter Co., 50 West 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METERS, GAS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, O.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Roots-Connersville Blower Corp., Connersville, Ind.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

METERS, PITOT
Pitometer Co., 50 Church St., New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

METER TESTING EQUIPMENT
Badger Meter Mfg. Co., Milwaukee, Wis.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
National Meter Division of Pittsburgh Equitable Meter Co., 4259 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Worthington-Gamon Meter Co., Newark, N. J.

METERS, VENTURI
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upham Sts., Philadelphia, Pa.

METERS, WATER & SEWAGE
Badger Meter Mfg. Co., Milwaukee, Wis.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
National Meter Division of Pittsburgh Equitable Meter Co., 4259 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Phoenix Meter Corp., Prince Bay, Staten Island, New York.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.
Worthington-Gamon Meter Co., Newark, N. J.

METER WASHERS
Mabbs Hydraulic Packing Co., 431 S. Dearborn St., Chicago, Ill.

MIXERS, CHEMICAL
The American Well Works, Aurora, Ill.
Carborundum Co., Niagara Falls, N. Y.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp.,, 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Mach. Co., Inc., 3409 E. 18th, Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

MIXERS, CONCRETE
(See Concrete Mixers)

MIXING EQUIPMENT
(Water & Sewage)
Ralph B. Carter Co., 53 Park Place, New York City.
Dorr Co., Inc., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.

MOTOR STARTERS
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

MOTORS, ELECTRIC
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.

NIPPLES, PIPE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Brass Co., Port Huron, Mich.

NOZZLES, FLOW
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chain Belt Co., Milwaukee, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

NOZZLES, SPRAY
Chain Belt Co., Milwaukee, Wis.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Mueller Brass Co., Port Huron, Mich.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

ODOR CONTROL
Cloroben Corp., 90 Forrest St., Jersey City, N. J.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Industrial Chemical Sales Div., West Va. Pulp & Paper Co., 230 Park Ave., New York City.
Permutit Co., 330 W. 42nd St., New York City.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc. 110 Washington St., Buffalo, N. Y.

ODOR & CARBON EVALUATION AIDS
Darco Corp., 60 E. 42nd St., New York City.
Industrial Chemical Sales Div., West Va. Pulp & Paper Co., 230 Park Ave., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
L. A. Salomon & Bro., 216 Pearl St., New York City.

OPERATING TABLES
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

ORIFICES
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

PACKING
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hyde-ro Rings (Ralph H. Hyde), P. O. Box 1, Campbell, Calif.
Johns-Manville, 22 E. 40th St., New York City.
Northrop & Co., Inc., 50 Church St., New York City.

PACKING, RAWHIDE
Mabbs Hydraulic Packing Co., 431 S. Dearborn St., Chicago, Ill.

PACKING RINGS
Water & Sewer Equip. Co., Rome, N. Y.

PACKING, SELF LUBRICATING
Greene, Tweed & Co., Bronx Blvd. at 238th St., New York City.

PAINT, ACID RESISTING
Atlas Mineral Prod. Co., Mertztown, Pa.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Quigley Co., Inc., 56 W. 45th St., New York City.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Wailes Dove-Hermiston Corp., Westfield, N. J.

PAINTS, TECHNICAL
Quigley Co., Inc., 56 W. 45th St., New York City.
Sherwood Waterproofing Corp., 53 Park Pl., New York City.

PENSTOCKS
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

pH CONTROL FEEDERS
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

pH METERS & pH TESTERS
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
E. Leitz, Inc., 730 Fifth Ave., New York City.
National Technical Laboratories, So. Pasadena, Calif.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

PIPE, ACID PROOF
American Cast Iron Pipe Co., Birmingham, Ala.
American Smelting and Refining Co., 120 Broadway, N. Y. C.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.
A. Wyckoff & Son Co., Elmira, N. Y.

PIPE AND TANK COATINGS
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Wailes Dove-Hermiston Corp., Westfield, N. J.

PIPE, ASBESTOS-CEMENT
Johns-Manville Co., 22 E. 40th St., New York City.

PIPE, BRASS AND COPPER
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Brass Co., Port Huron, Mich.

PIPE, CAST IRON
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 4th Ave., New York City.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE, CAST IRON SERVICE
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

PIPE, CEMENT LINED
American Cast Iron Pipe Co., Birmingham, Ala.
A. S. G. Pipe Lining Co., 304 W. 13 St., New York City.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Cement Lined Pipe Co., 93 Brookline St., Lynn, Mass.
Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
National Tube Co., Frick Bldg., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE, CEMENT LININGS
A. S. G. Pipe Lining Co., 304 W. 13 St., New York City.
Cement Lined Pipe Co., 93 Brookline St., Lynn, Mass.
Centriline Corp., 140 Cedar St., New York City.
Tate Pipe Linings, Inc., 47 Haverhill St., Andover, Mass.

PIPE, CONCRETE, PRESSURE
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Association, 33 W. Grand Ave., Chicago, Ill.

PIPE, COPPER
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.

PIPE, CORRUGATED
Armco Drainage Products Assn., Middletown, Ohio.

PIPE, CULVERT
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE CUTTING MACHINES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

PIPE, DRILLS, JACKS AND PUSHERS
Northrop & Co., Inc., 50 Church St., New York City.
Paris Mfg. Co., Paris, Ill.

PIPE ENAMELS, PROTECTIVE—COAL TAR
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Wailes Dove-Hermiston Corp., Westfield, N. J.

PIPE, FELT WRAPPING
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.

PIPE FITTINGS
American Cast Iron Pipe Co., Birmingham, Ala.
American Smelting and Refining Co., 120 Broadway, N. Y. C.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Carson-Cadillac Corp., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Clow and Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE—GALVANIZED, LIGHT-WEIGHT
(Quick Coupling, Transportable for Conveying Water)
Champion Corp., Hammond, Ind.

PIPE JOINT COMPOUNDS
Atlas Mineral Products Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Quigley Co., Inc., 56 W. 45th St., New York City.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.

PIPE JOINTS, MECHANICAL
Carson-Cadillac Corp., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
L. A. Weston, Adams, Mass.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE JOINT TOOLS
Atlas Mineral Prod. Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.

PIPE, LEAD LINED
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

PIPE LOCATORS
Aqua Survey & Instrument Co., 1409 Marlowe Ave., Cincinnati, Ohio.
Frank N. Blake, North Adams, Mass.
S. F. Ferguson, Douglas Hotel Bldg., Newark, N. J.
Northrop & Co., Inc., 50 Church St., New York City.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
Water Leak Detector Co., 166 N. Third St., Columbus, Ohio.

PIPE PUSHERS
Northrop & Co., Inc., 50 Church St., New York City.

PIPE, SEWER
American Cast Iron Pipe Co., Birmingham, Ala.
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Clow and Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill. (Reinforced Concrete)
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.
A. Wyckoff & Son Co., Elmira, N. Y.

PIPE, STEEL
American Rolling Mill Co., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
National Tube Co., Frick Bldg., Pittsburgh, Pa.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

PIPE, SUBAQUEOUS
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE TAPPING MACHINES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

PIPE TEST PLUGS
Northrop & Co., Inc., 50 Church St., New York City.

PIPE, WELDED STEEL
American Rolling Mill Co., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Crane Co., 836 S. Michigan Ave. Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co. Pittsburgh, Pa.

PIPE, WRAPPING
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.

PITOT TUBES
Pitometer Company, 50 Church St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

PLUGS
Standard Dry Wall Products, Inc., New Eagle, Pa.

PNEUMATIC CONVEYORS FOR WATER AND SEWAGE TREATMENT
Dracco Corp., Cleveland, Ohio.

PNEUMATIC CONVEYORS FOR WATER AND SEWAGE TREATMENT, BLOWERS FOR
Roots-Connersville Blower Corp., Connersville, Ind.

POROUS TUBES AND PLATES
Carborundum Co., Niagara Falls, N. Y.

POTENTIOMETERS
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.

PRESSURE REGULATORS
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Connelly Iron Sponge and Governor Co., 3154 S. California Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

PROPORTIONING EQUIPMENT (CHEMICAL)
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago. Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

PUMP MOTOR STARTERS
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

PUMP PRIMERS
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Roots-Connersville Blower Corp., Connersville, Ind.

PUMPS, ACID-HANDLING
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, BOILER FEED
The American Well Works, Aurora, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Economy Pump Inc., Hamilton, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Vogt Brothers Mfg. Co., Louisville, Ky.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, CELLAR DRAINER
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago Ill.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26 Los Angeles, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, CENTRIFUGAL
The American Well Works, Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Economy Pump Inc., Hamilton, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
Homelite Corp., Port Chester, N. Y.
Layne & Bowler, Inc., Memphis, Tenn.
Morris Machine Works, Baldwinsville, N. Y.
Northrop & Co., 50 Church St., New York City.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26 Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, CONDENSATION
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Economy Pump Inc., Hamilton, O.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26 Los Angeles, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, DEEP WELL
The American Well Works, Aurora, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26 Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, DIAPHRAGM
Ralph B. Carter Co., 53 Park Place, New York City.
Dorr Co., 570 Lexington Ave., New York City.
Edson Corp., 49 D St., South Boston, Mass.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
International Filter Co., 325 W. 25th St., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

PUMPS, DRAINAGE
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
S. Morgan Smith Co., York, Pa.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26 Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, HYDRANT
Edson Corp., 49 D St., South Boston, Mass.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.

PUMPS, JETTING
Northrop & Co., Inc., 50 Church St., New York City.

PUMPS, PORTABLE
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 So. Michigan Ave., Chicago, Ill.
Homelite Corp., Port Chester, N. Y.
Northrop & Co., Inc., 50 Church St., New York City.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26 Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, ROTARY
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26 Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Roots-Connersville Blower Corp., Connersville, Ind.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, SELF PRIMING
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Homelite Corp., Port Chester, N. Y.
Northrop & Co., 50 Church St., New York City.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Roots-Connersville Blower Corp., Connersville, Ind.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS SEWAGE
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Dorr Co., 570 Lexington Ave., New York City.
Economy Pumps, Inc., Hamilton, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26 Los Angeles, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, SLUDGE
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, SUCTION AND FORCE
Ralph B. Carter Co., 53 Park Place, New York City.
Edson Corp., 49 D St., South Boston, Mass.
Morris Machine Works, Baldwinsville, N. Y.
Northrop & Co., 50 Church St., New York City.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, SUMP
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Economy Pumps Inc., Hamilton, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.

Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, TURBINE
The American Well Works, Aurora, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26 Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, VACUUM
Barrett, Haentjens & Co., Hazleton, Pa.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumps Inc., Hamilton, O.
Gardner-Denver Co., Quincy, Ill.
Roots-Connersville Blower Corp., Connersville, Ind.
Vogt Brothers Mfg. Co., Louisville, Ky.
Worthington Pump & Mach. Corp., Harrison, N. J.

RAIN GAGES
M. C. Stewart, Ashburnham, Mass.

RATE OF FLOW CONTROLLERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

RATE OF FLOW RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Neptune Meter Co., 50 W. 50th St. New York City.
Northrop & Co., 50 Church St., New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

REAMERS
Mueller Co., Decatur, Ill.

RECARBONATORS
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

RECORDING INSTRUMENTS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

RECUPERATOR
Carborundum Co., Perth Amboy, N. J.

REFRACTORIES
Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.
Quigley Co., Inc., 56 W. 45th St., New York City.

REGULATORS, SEWAGE
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

REGULATORS (Pressure), WATER AND GAS
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Connelly Iron Sponge and Governor Co., 3154 S. California Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

RESERVOIRS
(See Standpipes and Tanks)

ROBOT FILTER AND SOFTENER OPERATORS
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

RUST PREVENTION
(Tanks, Pipe Lines, Submerged Metal)
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Cement Lined Pipe Co., 93 Brookline St., Lynn, Mass.
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio. (Cathodic Protection)
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio
Philadelphia Quartz Co., 124 S. Third St., Philadelphia, Pa.
Quigley Co., Inc., 56 W. 45th St., New York City.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Rusta Restor Corp., 1480 W. State St., Fremont, Ohio.
Wailes Dove - Hermiston Corp., Westfield, N. J.

SADDLES, PIPE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Mueller Co., Decatur, Ill
Northrop & Co., Inc., 50 Church St., New York City.

SAMPLERS AND SAMPLING TABLES
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Proudman & Goossen, New Canaan, Conn.
Roberts Filter Mfg. Co., Darby, Pa.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

SAND EXPANSION INDICATORS
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

SCALE PREVENTION CHEMICALS
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Permutit Co., 330 W. 42nd St., New York City.

SCREENS, INTAKE
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SCREENS, SAND, GRAVEL AND STONE
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SCREENS, SEWAGE
The American Well Works, Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

SCREENS, WATER WELL
Layne & Bowler, Inc., Memphis, Tenn.

SERVICE BOXES
Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 So. Michigan Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.

SEWAGE EJECTORS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

SEWAGE SAMPLERS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Proudman & Goossen, New Canaan, Conn.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

SEWAGE SCREENING GRINDERS
The American Well Works, Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Royer Foundry & Mach. Co., Kingston, Pa.

SEWAGE SLUDGE INCINERATOR
Dorr Co., 570 Lexington Ave., New York City.
Nichols Engineering & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Underpinning & Foundation Co., 155 E. 44th St., New York City.

SEWER CLEANERS
Champion Corp., Hammond, Ind.
Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

SEWER DESIGN—CONCRETE
(Literature, Information, Advice)
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

SEWER PIPE
(See Pipe, Sewer)

SEWER PIPE JOINTS
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
L. A. Weston, Adams, Mass.

SEWER PIPE LOCATORS
Frank N. Blake, North Adams, Mass.

SEWER RODS
Champion Corp., Hammond, Ind.
Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

SHEETING
Armo Drainage Products Assn. Middletown, Ohio.

SIGHT FEEDERS
(For Chemical Pumps)
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

SIPHONS (SEWAGE)
Armco Drainage Products, Assn., Middletown, Ohio.
Ralph B. Carter Co., 53 Park Place, New York City. (Alternating.)
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

SLEEVES, PIPE REPAIR
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

SLEEVES, TAPPING (VALVE)
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
M. & H. Valve & Fittings Co., Anniston, Ala.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.

SLUDGE COLLECTORS
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pemutit Co., 330 W. 42nd St., New York City.

SLUDGE DISINTEGRATORS
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Royer Foundry & Mach. Co., 158 Pringle St., Kingston, Pa.

SLUDGE PUMPS
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

SODA ASH
Diamond Alkali Co., Pittsburgh, Pa.
Innis, Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Works, 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt. Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
Solvay Sales Corp., 40 Rector St., New York City.

SODIUM ALUMINATE
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

SODIUM PHOSPHATES (GLASSY)
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.

SODIUM SILICATE
Diamond Alkali Co., Pittsburgh, Pa.
General Chemical Co., 40 Rector St., New York City.
Philadelphia Quartz Co., 124 S. Third St., Philadelphia, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Standard Silicate Division, Diamond Alkali Co., Pittsburgh, Pa.
Tamms Silica Co., 228 N. LaSalle St., Chicago, Ill.

SOFTENERS AND PURIFIERS
Calgon, Inc., Hagan Bldg., Pittsburgh,, Pa.
Cloroben Corp., 225 Mercer St., Jersey City, N. J.
Dorr Co., Inc., 570 Lexington Ave., New York City.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.

SPEED REDUCERS, TRANSMISSION
De Laval Steam Turbine Co., Trenton, N. J.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.

SPRINKLING FILTER PLANTS
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

STACKS
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

STACKS, FUME
Johns-Manville, 22 E. 40th St., New York City.

STANDPIPE AND TANKS
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

STANDPIPE PRESERVATION
(Cathodic Protection Process)
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio.

STIRRERS (LABORATORY)
Dorr Co., 570 Lexington Ave., New York City.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.

STOKERS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Link-Belt Co., 2410 W. 18th St., Chicago, Ill.

STORAGE TANKS
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

STRAINERS, SUCTION
Barrett, Haentjens & Co., Hazleton, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Edson Corp., 49 D St., South Boston, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.

SULPHATE OF ALUMINA
Activated Alum Corp., Curtis Bay, Baltimore, Md.
General Chemical Co., 40 Rector St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.

SULPHUR DIOXIDE (LIQUID)
Ansul Chemical Co., P. O. Box 231, Marinette, Wis.
Virginia Smelting Co., West Norfolk, Va.

SUPER-CHLORINATION UNITS
(See Chlorinators)

SWIMMING POOL EQUIPMENT
Ralph B. Carter Co., 53 Park Place, New York City.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

SWIMMING POOL TESTING OUTFITS (pH and Chlorine)
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

SWITCHES, FLOAT, TRANSFER AND REMOTE CONTROL
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

TANKS, ELEVATED STEEL
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

TANK PRESERVATION
(Cathodic Protection Process)
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio.

TANKS, RUBBER LINED
Atlas Mineral Products Co., Mertztown, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

TANKS, STEEL
(See Tanks, Elevated Steel)

TAPPING MACHINES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

TASTE & ODOR CONTROL GRAPHS
Darco Corp., 60 E. 42nd St., New York City.

TASTE & ODOR REMOVAL CHEMICALS
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Ansul Chemical Co., P. O. Box 231, Marinette, Wis.
Cloroben Corp., 225 Mercer St., Jersey City, N. J.
Darco Corp., 60 E. 42nd St., New York City.
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., Inc., 230 Park Ave., New York City.
Permutit Co., 330 W. 42nd St., New York City.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

TESTERS, WATER METER
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
National Meter Division of Pittsburgh Equitable Meter Co., 4221 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Worthington-Gamon Meter Co., Newark, N. J.

THICKENERS
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

TOOLS, PNEUMATIC
Schramm, Inc., Westchester, Pa.

TRAPS, DRIP, FLAME, SEDIMENT
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

TRICKLING FILTERS, HIGH RATE, HIGH CAPACITY
The American Well Works, Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Co., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

TRITURATORS
(See also Grinders)
Chain Belt Co., Milwaukee, Wis.

TUNNEL LINER PLATES
Armco Drainage Prod. Assn., Middletown, Ohio.

TUNNEL MACHINERY, BORING & LINING
Jeffery Mfg. Co., Columbus, Ohio.

TURBINES, HYDRAULIC
De Laval Steam Turbine Co., Trenton, N. J.
Morris Machine Works, Baldwinsville, N. Y.
S. Morgan Smith Co., York, Pa.

TURBINES, STEAM
De Laval Steam Turbine Co., Trenton, N. J.
Morris Machine Works, Baldwinsville, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

VALVE BOXES
Central Foundry Co., 386 Fourth Ave, New York City.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVE BOX LOCATORS
Aqua Survey & Instrument Co., 1409 - Marlowe Ave., Cincinnati, Ohio.

VALVES
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Armco Drainage Products Assn., Middletown, Ohio.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
S. Morgan Smith Co., York, Pa.
Vogt Bros. Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVES, AIR RELEASE
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, AIR & VACUUM
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.
Roots-Connersville Blower Corp., Connersville, Ind.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. D. Wood Co., 400 Chestnut St., Chicago, Ill.

VALVES, ALTITUDE
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 So. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Northrop & Co., Inc., 50 Church St., New York City.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.

VALVES, CHECK
Barrett, Haentjens & Co., Hazleton, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Connelly Iron Sponge and Governor Co., 3154 So. California Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
R. D. Wood Co., Philadelphia, Pa.

VALVES, CHLORINE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

VALVES, CONE,
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, EMERGENCY TRIP
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.

VALVES, FLAP
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Connelly Iron Sponge and Governor Co., 3154 So. California Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, FLOAT
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Northrop & Co., Inc., 50 Church St., New York City.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

VALVES, FOOT
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Edson Corp., 49 D St., South Boston, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, FOUR WAY
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Roberts Filter Mfg. Co., Darby, Pa.

VALVES, GATE
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVES, HYDRAULIC CYLINDER OPERATED
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, MOTOR OPERATED
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, MUD AND PLUG
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Brothers Mfg. Co., Louisville, Ky.

VALVES, PRESSURE REDUCING
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Connelly Iron Sponge and Governor Co., 3154 So. California Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith, York, Pa.

VALVES, PUMP
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

VALVES, RELIEF
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Decatur, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

VALVES, RUBBER, GLASS AND LEAD LINED
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.

VALVES, SPECIAL AUTOMATIC
Barrett, Haentjens & Co., Hazleton, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Northrop & Co., Inc., 50 Church St., New York City.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, WATER METER SPECIAL
Ford Meter Box Co., Wabash, Ind.

VARIABLE SPEED TRANSMISSIONS
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

VENTURI TUBES
Bailey Meter Co., 1072 Ivanhoe, Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

VIBRATORS, ELECTRO-MAGNETIC
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

WASTE GAS BURNERS
Ralph B. Carter Co., 53 Park Place, New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

WATER ANALYSIS EQUIPMENT AND REAGENTS
Chemlab Specialties Co., 52 Alvarado Road, Berkeley, Calif.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

WATER HAMMER ARRESTERS
Water Hammer Arrester Corp., 161 W. Wisconsin Ave., Milwaukee, Wis.

WATER LEAK, LOCATING INSTRUMENTS
S. F. Ferguson, Douglas Hotel Bldg., Newark, N. J.
Northrop & Co., Inc., 50 Church St., New York City.
Pitometer Co., 50 Church St., New York City.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Water Leak Detector Co., 166 N. Third St., Columbus, Ohio.

WATER LEVEL RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

WATER MAIN CLEANING
National Water Main Cleaning Co., 50 Church St., New York City.
Flexible Underground Pipe Cleaning Co., 9059 Venice Blvd., Los Angeles, Calif.

WATERPROOFING PAINTS, COMPOUNDS AND MATERIALS
General Paint Corp., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.
Quigley Co., Inc., 56 W. 45th St., New York City.
Reilly Tar & Chem Co., Merchants Bank Bldg., Indianapolis, Ind.
Sherwood Waterproofing Corp., 53 Park Pl., New York City.
Wailes Dove-Hermiston Corp., Westfield, N. J.

WATER SOFTENING CHEMICALS AND COMPOUNDS
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
National Lime Assn., 927 Fifteenth St. N. W. Washington, D. C.
Permutit Co., 330 W. 42nd St. New York City.
Pittsburgh Plate Glass Co. Columbia Chemical Div. 30, Rockefeller Plaza, New York City.
Zeolite Chemical Co., 140 Cedar St., New York City.

WATER SOFTENING EQUIPMENT
The American Well Works, Aurora, Ill.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dorr Co., Inc., 570 Lexington Ave., New York City.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 3409 E. 18th, Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Zeolite Chemical Co., 140 Cedar St., New York City.

WATER STABILIZATION
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

WATER SUPPLY CONTRACTORS
Ranney Water Collector Corp. of New York, 1510 Heyburn Bldg., Louisville, Ky.

WATER TREATMENT FOR SCALE AND CORROSION
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.

WATER WASTE SURVEYS
Aqua Survey & Instrument Co., 1400 Marlowe Ave., Cincinnati, Ohio.
S. F. Ferguson, Douglas Hotel Bldg., Newark, N. J.
Pitometer Co., 50 Church St., New York City.
Simplex Valve & Meter Co. 68th & Upland Sts., Philadelphia, Pa.

WEATHER INSTRUMENTS
M. C. Stewart, Ashburnham, Mass.

WEATHERPROOF PAINTS, ROOF COATINGS
General Paint Corp., 3091 Mayfield Road, Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.
Quigley Co., Inc., 56 W. 45th St., New York City.
Reilly Tar & Chem. Co., Merchants Bank Bldg., Indianapolis, Ind.
Sherwood Waterproofing Corp., 53 Park Pl., New York City.

WEIGH FEEDER MACHINES
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Merrick Scale Mfg. Co., 180 Autumn St., Passaic, N. J.
Omega Machine Co., 3409 E. 18th, Kansas City, Mo.

WELL WATER SUPPLY SYSTEMS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ranney Water Collector Corp. of New York, 1510 Heyburn Bldg., Louisville, Ky.

WIND VANES
M. C. Stewart, Ashburnham, Mass.

WRAPPING, PIPE
(See Pipe, Wrapping)

WRENCHES, REVERSIBLE RATCHET
Dresser Mfg. Co., Bradford, Pa.
Greene, Tweed & Co., Bronx Blvd. at 238th St., New York City.

ZEOLITE AND ZEOLITE SOFTENERS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.
Zeolite Chemical Co., 140 Cedar St., New York City.

INFORMATION ON WATER AND SEWAGE WORKS PROBLEMS

(WHERE TO FIND IT)

By LINN H. ENSLOW

Editor, "Water Works and Sewerage"

IT goes without saying that information required by water works men and sewage works operators is not concentrated in two or three books. The nearest approach to concentrated information for water works men is found in the manuals published by the American Water Works Association—"Water Works Practice," the "Purification Manual and the "Accounting Manual."

Text books, manuals, hand-books, journals, and catalogs are named in the attached list of recommended reference works for water and sewage works men.

The list represents the majority opinions of operating men, managers, engineers and chemists called on to offer suggestions in making up a set of reference works. It is an attempt to recommend those books of greatest usefulness.

LIST NO. 1 —FOR WATER WORKS MANAGERS AND OPERATORS

[For Small and Moderate Size Systems.]

Books	*Publishers*	*Authors*
Water Works Practice—Manual of the A. W. W. A. ($5.00)	Williams & Wilkins, Baltimore	Various
Manual of Water Works Accounting	Am. Water Works Assn., New York City	Various
Manual of Water Quality and Treatment	Am. Water Works Assn., New York City	Various
The Operation of Water Filtration Plants (F)	N. C. State Dept. Health, Raleigh, N. C	
Water Supply Control (nominal charge)	N. Y. State Dept. Health, Albany, N. Y	
Water Works Handbook ($7.00)	McGraw-Hill Co., New York City	Flynn, Weston & Bogert
Water Purification Control, 2nd Edition ($1.75)	Williams & Wilkins, Baltimore, Md	Hopkins
Standard Methods of Water Analysis, 8th Ed. ($2.50)	A. P. H. A. and A. W. W. A., New York City	Various
Lab. Manual—Chemical & Bacterial Analysis Water and Sewage, 2nd Edition ($2.50)	McGraw Hill Co., New York City	Theroux, Eldridge, Mallman
Water Purification ($7.00)	McGraw Hill Co., New York City	Ellms
Copper Sulphate in Control of Micro Organisms (F)	Phelps Dodge Refining Corp., New York City	Hale
Pump Data (F)	Economy Pumping Mach. Co., Chicago	
Conversion Factors for Engineers (F)	The Dorr Co., New York City	
Engineering Data in Flow of Fluids in Pipes (F)	Crane Co., Chicago	
Bul. No. 21 (a Handbook on Hydraulics) (F)	National Tube Co., Pittsburgh, Pa	
Handbook of Cast Iron Pipe (F)	Cast Iron Pipe Research Assn., Chicago	
Elements of Water Supply Engineering (2nd Ed.)	John Wiley & Sons, New York City	Waterman
Technical Bulletins on Chlorination (F)	Wallace & Tiernan Co., Newark, N. J	Various
Hydraulic Tables—3rd Ed. ($2.00)	John Wiley & Sons, New York City	Williams & Hazen
Handbook on Fire Protection ($4.50)	D. Van Nostrand Co., New York City	Crosby, Fiske & Forster
Fire Engine Tests and Fire Stream Tables (F)	National Board of Fire Underwriters, N. Y. C	
Plumber's Handbook ($4.00)	McGraw-Hill Co., New York City	Dibble
Examination of Water—6th Ed. ($3.00)	John Wiley & Sons, New York City	Mason & Buswell
Public Water Supplies—4th Ed. ($6.00)	John Wiley & Sons, New York City	Turneaure & Russell
American Civil Engineering Handbook—5th Ed. ($8.00)	John Wiley & Sons, New York City	Merriman & Wiggin
Lefax—Data Sheets for Loose Leaf Note Books	Lefax, Inc., Philadelphia, Pa	Various
Water Supply & Treatment (F)	National Lime Assn., Washington, D. C	Hoover
Treatment of Municipal and Industrial Waters—Tech. Bul. No. 8 (F)	The Solvay Process Co., New York City	
A. B. C. of Hydrogen Ion Control (F)	LaMotte Company, Baltimore, Md	
Modern P. H. Control (F)	W. A. Taylor Co., Baltimore, Md	
Microscopy of Drinking Water (4th Ed. $7.00)	John Wiley & Sons, New York City	Whipple-Fair
Plane Surveying ($3.50)	John Wiley & Sons, New York City	Tracy
Water Purification for Plant Operators ($2.50)	McGraw-Hill Co., New York City	Norcom and Brown
Water Treatment and Purification ($2.50)	McGraw Hill Co., New York City	Ryan
Water Rate Structures in America (F)	Public Service Commission of Wisconsin, Madison, Wis	

(F) Available as Free Publication at this writing.

Journals and Magazines (*Applies to Lists* 1 *and* 2)

Journal and Monographs of the American Waterworks Association

Journal of the New England Water Works Association.

Current Water Works Technical Magazines and Trade Papers.

LIST NO. 2—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE WATER WORKS

(In addition to List No. 1)

Books	*Publishers*	*Authors*
Fresh Water Biology ($7.00)	John Wiley & Sons, New York City	Ward & Whipple
Fresh Water Algae ($6.00)	McGraw-Hill Co., New York City	Smith
Ground Water ($6.00)	McGraw-Hill Book Co., New York City	C. F. Tolman
Design of Dams ($5.00)	McGraw-Hill Boook Co., New York City	Hanna and Kennedy
Elements of Water Bacteriology—5th Ed. ($2.50)	John Wiley & Sons, New York City	Prescott & Winslow
"Industrial Water Supplies" (nominal charge)	Ohio Geological Survey, Columbus, Ohio	C. W. Foulk
pH and Its Practical Application ($3.50	Williams & Wilkins Co., Baltimore, Md	LaMotte, Kenny & Reed
Elimination of Tastes and Odors in Water ($5.00)	McGraw-Hill Co., New York City	Baylis
Boiler Feedwater Purification ($4.00)	McGraw-Hill Co., New York City	Powell
Chemistry of Water and Sewage Treatment****	Chemical Catalog Company, New York City****	Buswell
Water Borne Typhoid Fever Outbreaks (nominal)	Am. Public Health Bureau	Wolman & Gorman
Textbook of Bacteriology ($8.00)	D. Appleton & Co., New York City	Zinser & Jones
Corrosion; Causes and Prevention ($7.00)	McGraw-Hill Co., New York City	Speller
Water Supply Paper No. 658 (Quality of Waters) (nominal)	U. S. Geological Survey, Washington, D. C.	Stabler
Water Supply and Sewerage ($5.00)	McGraw-Hill Co., New York City	Steel
Water Supply Engineering (3rd Ed. $6.00)	McGraw-Hill Co., New York City	Babbitt & Doland
Handbook of Hydraulics ($4.00)	McGraw-Hill Co., New York City	King
Concrete Engineers' Handbook ($6.00)	McGraw-Hill Co., New York City	Hool & Johnson
Pocket Companion (nominal)	Carnegie Steel Corp., New York City	
Business Law for Engineers ($4.00)	McGraw-Hill Co., New York City	Allen
Mechanical Engineers' Handbook—11th Ed. ($5.00)	John Wiley & Sons, New York City	Kent
Elements of Hydraulics ($1.50)	John Wiley & Sons, New York City	Merriman
The Hardy Cross Method of Distribution System Design.	Univ. of Illinois Engr. Exp. Sta. Bul. No. 286	Hardy Cross
Guiding Principles of Public Service Regulations (3 Vols.)	Public Utilities Reports, Inc., Rochester, N. Y.	Spurr
Theory and Practice of Public Utility Valuation****	McGraw-Hill Co., New York City****	Maltbie
Public Utility Rates****	McGraw-Hill Co., New York City****	Barker
Public Utility Rate Structures ($4.00)	McGraw-Hill Co., New York City	*Nash*
Census of Munic. Water Purification Plants (nominal)	Am. Water Works Assn., New York City	
Business Administration for Engineers ($5.00)	McGraw-Hill Co., New York City	Harding & Canfield
Census of Municipal Water Purification Plants (50c)	Am. Water Wks. Assn., New York City	
Index to Jour. of A. W. W. A.—1881-1933 ($2.50)	Am. Water Wks. Assn., New York City	

****Out of print. Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.

For Journals see list No. 1.

LIST NO. 3—FOR OPERATORS AND MANAGERS OF SMALL SEWAGE WORKS**

Books	*Publishers*	*Authors*
Principles of Sewage Treatment (F)	National Lime Assn., Washington, D. C	W. Rudolfs and Staff
Operation and Control of Sewage Treatment Plants	New York State Dept. Health	N. Y. State Dept. Health
Sewage Treatment ($3.00)	John Wiley & Sons, Inc., New York City	Imhoff and Fair
Sewerage and Sewage Disposal Text Book ($6.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Sewage Treatment Works ($6.00)	McGraw-Hill Book Co., New York City	Keefer
Bulletins Nos. 59, 68, 69, 84 and 86 (F)	Iowa State College, Ames, Iowa	Various
Manual of Sewage Works Operation (nominal)	New Jersey Sewage Expt. Sta., New Brunswick, N. J	
Reprints of Technical Papers on Chlorine in Sewage Treatment (F)	Wallace & Tiernan Co., Newark, N. J	Various
Chlorination in Sewage Treatment (F)	Amer. Pub. Health Assn., N. Y. C.	Committee Reports
Chemical Treatment of Sewage (nominal)	Amer. Pub. Health Assn., N. Y. C.	Committee Report
Standard Methods of Water and Sewage Analysis ($2.50)	Amer. Pub. Health Assn., N. Y. C.	A. W. W. A.-A. P. H. A.
Laboratory Manual of Water and Sewage Analysis ($2.50)	McGraw-Hill Co., New York City	Theroux, Eldridge & Mallman
Sewer Rentals ($1.50)	Am. Public Works Assn., Chicago	Various

Journals and Magazines

Sewage Works Journal—(Official publication, Sewage Works Federation)
Current Sewerage Magazines

LIST NO. 4—FOR MANAGER, CHEMISTS AND OPERATORS OF LARGE SEWAGE WORKS**

(In addition to List No. 3)

Books	*Publishers*	*Authors*
American Sewage Practice Vol. 3, Sewage Treatment (1935 Edition) ($7.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Solving Sewage Problems ($6.00)	McGraw-Hill Co., New York City	Fuller & McClintock
Sewerage and Sewage Treatment—4th Ed. ($5.00)	John Wiley & Sons, New York City	Babbitt
The Chemistry of Water and Sewage Treatment****	Chemical Catalog Co., New York****	Buswell
The Hoover Plumbing Code (B. H. 13) (nominal)	U. S. Bureau of Standards	
Sewerage and Sewage Treatment—5th Ed. ($5.00)	Intl. Text Book Co., Scranton, Pa	Hardenberg
Sewerage, 11th Ed. ($4.50)	John Wiley & Sons, New York City	Folwell
Sewage Disposal****	John Wiley and Sons, New York City****	Kinnicutt, Winslow & Pratt
Modern Sewage Disposal ($3.50)	Federation of Sewage Works Assns., New York City	Various
Sewers (25 shillings)	Chapman & Hall, London	Bevan and Rees
Industrial Waste Treatment Practice	McGraw-Hill Co., New York City	Eldridge

(F) Available as Free Publication at this writing.
****Out of print. Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.

***Note*—Sewerage men should examine Lists 1 and 2—also for several (F) publications of value to all alike—for instance, "Conversion Factors for Engineers" and the hand-books of pipe and pump data.

PART I. WATER

FLOW, FRICTION, MEASUREMENT AND POWER

The rate of flow or the volume of water passing a cross section of a stream in a unit time is called the "discharge." If a uniform velocity at all points in the cross section of a stream were possible, there would be passing any cross section of the stream, every unit of time, a prism of water having a base equal to the cross-sectional area of the stream and a length equal to the velocity. However, due to the varying effects of friction and viscosity, the different filaments of water move with different velocities. For this reason it is common in hydraulics to deal with "mean velocities."

The discharge may be expressed in terms of the mean velocity:

$$Q = av$$

where Q = Discharge in cubic feet per second.
a = Cross-sectional area of stream in square feet.
v = Mean velocity in feet per second.

When the discharge is constant (i.e., when the same quantity of water passes any cross section of a stream during equal successive intervals of time) the flow is said to be "steady."

Flow is said to be "uniform" when there is little or no change in the cross section or velocity from point to point in a stream.

Thus uniform flow implies similarity of conditions at successive cross sections at any given instant, while steady flow involves permanency of conditions at any particular cross section.

In hydraulics the term "pressure head," "static head" or simply "head" is used to designate the vertical height of a static column of liquid which, due to its weight, would produce a pressure equivalent to the pressure in the fluid at the point in question.

The "velocity head" is the height through which a body must fall in a vacuum to acquire the velocity with which water flows in a stream. The velocity head corresponding to any velocity is equal to the static head, which (neglecting friction) could cause (or could be caused by) that velocity. The relation between velocity head and velocity may be expressed by the formula:

$$h_v = \frac{v^2}{2g}$$

where h_v = Velocity head in feet.
v = Mean velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.

Flow of Water Through Orifices and Tubes

As commonly used in hydraulics, the term orifice is used to designate an opening with a closed perimeter, and of regular shape, through which water flows. If the perimeter is not closed, or if the opening flows only partially full, the orifice becomes a weir.

An orifice with prolonged sides, such as a short piece of pipe two or three diameters in length, set in the side of a reservoir, is called a tube. An orifice in a thick wall has the hydraulic properties of a tube.

The theoretical velocity of a stream or jet of water issuing from an orifice is given by the formula:

$$v_t = \sqrt{2gh}$$

where v_t = Theoretical velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.
h = Head on the center of the orifice in feet.

The actual velocity of the jet is less than the theoretical velocity because of the frictional loss which occurs as the water approaches the orifice. The ratio of the actual mean velocity, v, to the theoretical velocity, v_t, is called the "velocity coefficient" and is designated by the symbol C_v. The actual mean velocity of the jet is therefore:

$$v = C_v\sqrt{2gh}$$

The stream or jet issuing from an orifice is not in all cases the same size as the opening of the orifice because of contraction effects in certain cases and flaring effects in other cases. The "contraction coefficient," C_c, of an orifice is the ratio of the cross-sectional area of the jet to that of the orifice.

The discharge from an orifice is given by the formula:

$$Q = C_vC_ca\sqrt{2gh}$$

where Q = Discharge in cubic feet per second.
a = Area of orifice opening in square feet.

It is customary to combine the coefficients C_v and C_c into a single coefficient C_d which is called a "discharge coefficient." The discharge coefficient is therefore a product of the velocity coefficient and the contraction coefficient, or $C_d = C_v \times C_c$.

The formula for discharge from an orifice then becomes:

$$Q = C_da\sqrt{2gh}$$

Table 12 gives average values of discharge coefficients for various types of orifices and tubes.

Flow of Water in Pipe and Open Channels

As the term is used in hydraulics, a pipe may be defined as a closed conduit which flows full under pressure. By open channel is meant any kind of water course with the top surface of the flowing water exposed to the atmosphere, such as a canal, aqueduct, flume, sewer or river.

The "wetted perimeter" of any conduit is that portion of the perimeter of the cross section of the conduit in contact with the liquid.

The "hydraulic radius" of a conduit is the cross-sectional area of the stream, divided by the wetted perimeter of that section. For a circular pipe flowing either full or half full the hydraulic radius is one-fourth the pipe diameter (or one-half the pipe radius).

If a tube is tapped into the wall of a vessel or pipe containing water under pressure, the water will rise in the tube to a height equal to the head producing the pressure at the point where the tube is inserted. Such a tube is called a "piezometer" tube. Piezometer tubes measure pressure above atmospheric pressure (gage pressure) since the water surface in the tube is subjected to atmospheric pressure. When piezometer tubes are used to measure pressure heads in pipes where water is in mo-

Table 12
Discharge Coefficients for Various Types of Orifices and Tubes

Diagram	Description	Average discharge coefficient, C_d
	SHARP-EDGED ORIFICE The stream is contracted to about 0.62 of the area of the opening.	0.61
	ORIFICE WITH WELL-ROUNDED ENTRY There is little or no contraction and the stream is about the same size as the opening.	0.98
	SHORT TUBE OR ORIFICE IN THICK WALL WITH SQUARE-EDGED ENTRY When flowing full. When the length of the tube is 2½ diameters it is called a "standard short tube".	0.82
	SHORT TUBE OR ORIFICE IN THICK WALL WITH SQUARE-EDGED ENTRY When the stream springs clear from the tube at the upstream corner the flow is the same as for a sharp-edged orifice.	0.61
	RE-ENTRANT TUBE Length about 2½ diameters. Flowing full.	0.73
	RE-ENTRANT TUBE When the length is about one diameter it is called "Borda's Mouthpiece". Stream springs clear of the walls of the tube.	0.52

*The material under this heading has been drawn from National Tube Company's Technical Bulletin No. 21.

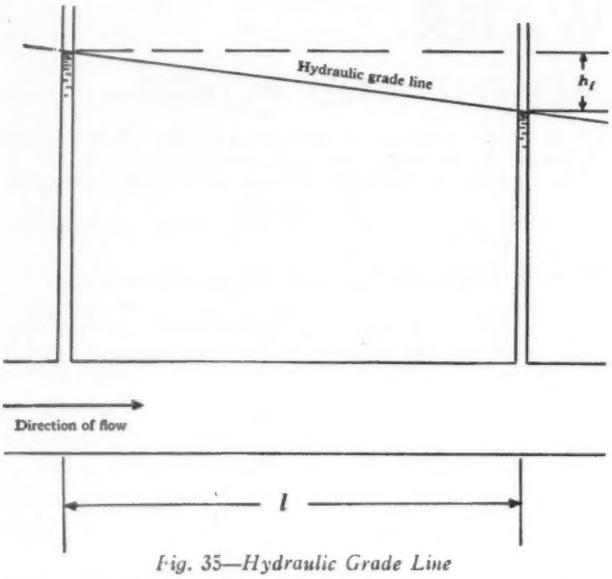

Fig. 35—Hydraulic Grade Line

tion, the end of the tube should enter the pipe at right angles to the direction of flow and the end of the tube should be flush with the inner surface of the pipe.

If a pipe full of water is provided with several piezometer tubes, a line joining the tops of the columns of water in the tubes is called the "hydraulic grade line," and the slope of this line is the "hydraulic slope" or simply the "slope." Two piezometer tubes attached to a pipe line are shown in Fig. 35. The line joining the tops of the columns of water in the tubes represents the hydraulic grade line and h_f represents the loss of head in length l. The hydraulic slope, s, is therefore:

$$s = \frac{h_f}{l}.$$

Friction

There is always friction between moving water and the surface with which the water comes into contact. There is also friction between the moving particles of the water themselves which is commonly called viscosity.

Water particles in contact with the conduit surface are retarded by friction, and viscosity causes a retardation of the particles removed from the conduit surface. Therefore, water flowing in a pipe has its maximum velocity at the center and its minimum velocity near the pipe walls.

If there were no friction losses, the theoretical velocity, v_t, at which water would discharge from a pipe or channel would be $v_t = \sqrt{2gh}$. In any long pipe or channel, however, the greater portion of the total head is used in overcoming friction.

The amount of frictional resistance offered by any surface increases with the degree of roughness of the surface. The resistance due to viscosity decreases as the temperature of the water increases.

The loss of head due to the combined effects of viscosity and friction between the moving water and the surface of the conduit is usually referred to as the loss of head due to friction.

The influences of friction and viscosity on the flow of water have been determined experimentally by various authorities and a variety of formulas for the loss of head due to friction have been derived. Only a few of the best-known and most generally used formulas will be presented in this article.

In addition to the loss of head due to friction, other losses of head result from changing the velocity or direction of flow. These special losses are considered in Table 21.

Formulas for Flow of Water In Pipe and Open Channels

The Chezy Formula

The most generally used formula for determining the velocity of flow of water in pipe and open channels is the Chezy Formula:

$$v = c\sqrt{rs}, \text{ or } v = cr^{0.5}s^{0.5}$$

where v = Mean velocity in feet per second.
r = Hydraulic radius in feet.
s = Hydraulic slope in feet per foot of length.
c = A coefficient which Chezy considered to be constant, but which is now known to vary with the hydraulic slope and hydraulic radius as well as with the degree of roughness of the surface with which the water comes in contact.

This formula, although originally designed for open channels, is with proper modification applicable to either open channels or pipe.

The Hazen-Williams Formula

For the same degree of roughness, the value of c for the Chezy Formula increases with the hydraulic slope and with the hydraulic radius. This is due to the fact that the exponents used for the terms in the formula are less than the true values. If the exponents were increased to correspond more nearly with the facts, the variation in the value of c would become smaller.

The Hazen-Williams Formula was designed with a view of obtaining a minimum variation in the value of c for all conduits of the same degree of roughness. That is, the object was to select values for the exponents such that c would be, as nearly as practicable, a function of the degree of roughness of the conduit surface and not of the hydraulic radius and slope.

The Hazen-Williams Formula is:

$$v = cr^{0.63}s^{0.54}0.001^{-0.04}$$

where v = Mean velocity in feet per second.
r = Hydraulic radius in feet.
s = Hydraulic slope in feet per foot of length.
c = Hazen-Williams coefficient of roughness.

The last term ($0.001^{-0.04}$) is a constant, and was introduced simply to equalize the value of c with the value in the Chezy Formula and other exponential formulas which may be used as a slope of 0.001 instead of at a slope of 1. Since $0.001^{-0.04}$ equals 1.318, the Hazen-Williams Formula may be written:

$$v = 1.318cr^{0.63}s^{0.54}$$

Values of Coefficient "C"

The following values of the coefficient c may be used in the Hazen-Williams Formula for computing the loss of head due to friction in new well-laid pipe:

Kind of Pipe	Coefficient c	Kind of Pipe	Coefficient c
National Duroline	148*†	Wood Stave	120
Wrought Steel	140	Riveted Steel	110
Small Brass and Copper	130	Vitrified Pipe	110
Cast Iron	130	Brick Sewers	100
Concrete	120		

*"Duroline" pipe is protected against internal corrosion and mounting friction losses by a cement base composition lining of a highly durable nature.—Ed.

†Approximately the same for cement lined pipe.—Ed.

It must be understood that these values depend upon the smoothness and regularity of the surfaces and are likely to vary in individual cases. In designing a pipe line it is customary to use somewhat lower coefficients than those above, to allow for variations due to local conditions, and for reduction of carrying capacity with age due to roughening of the inside surface, accumultaion of corrosion products, and tuberculation. However, in case of Duroline Pipe, the volume of flow remains practically unchanged over long periods of service due to the fact that rust tubercles do not form and the initially smooth inside surface is retained.

Tables 15 and 16 have been prepared to furnish directly the loss of head (h_f) in feet per 1000 feet of pipe of various sizes for different velocities and values of the coefficient c. Similar data for Duroline Pipe, based on a value of $c = 148$, is given in Table 17. These tables were calculated for actual internal diameters by the following arrangement of the Hazen-Williams Formula:

$$h_f = 1000\sqrt[0.54]{\frac{v}{1.318\,cr^{0.63}}}$$

where h_f = Loss of head in feet due to friction per 1000 feet of pipe = $1000s$.

The loss of head (h_f) for any value of the coefficient c not given in Tables 15 and 16 may be determined by multiplying the loss of head (h_f) for $c = 100$ by the factor $\sqrt[0.54]{\frac{100}{c}}$.

Values of this factor corresponding to various values of the coefficient c are given below:

Coefficient c	Factor $= \sqrt[0.54]{\frac{100}{c}}$	Coefficient c	Factor $= \sqrt[0.54]{\frac{100}{c}}$
60	2.575	110	0.8382
70	1.936	120	.7135
80	1.512	130	.6152
90	1.215	140	.5363
100	1.000		

Table 15
Loss of Head in Pipe by Friction for National A.P.I. Line Pipe, Calculated by Hazen-Williams Formula

Pipe size inches	Inside diameter inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=120$	$c=100$	$c=80$
1	1.049	3	4,320	1.114	6.72	8.94	12.5	18.9
		4	5,760	1.485	11.4	15.2	21.4	32.3
		5	7,200	1.856	17.3	23.0	32.3	48.8
		6	8,640	2.227	24.3	32.3	45.2	68.4
		8	11,520	2.970	41.3	55.0	77.1	117.
		10	14,400	3.712	62.5	83.1	117.	176.
		12	17,280	4.455	87.6	117.	163.	247.
		16	23,040	5.940	149.	198.	278.	421.
		20	28,800	7.425	226.	300.	421.	636.
		25	36,000	9.281	341.	454.	636.	961.
		30	43,200	11.137	478.	636.	891.	1347.
		35	50,400	12.993	636.	846.	1185.	1792.
		40	57,600	14.849	814.	1083.	1518.	2295.
1¼	1.380	4	5,760	0.858	3.01	4.01	5.61	8.49
		5	7,200	1.073	4.55	6.06	8.49	12.8
		6	8,640	1.287	6.38	8.49	11.9	18.0
		8	11,520	1.716	10.9	14.5	20.3	30.6
		10	14,400	2.145	16.4	21.9	30.6	46.3
		12	17,280	2.574	23.0	30.6	42.9	64.9
		16	23,040	3.432	39.2	52.2	73.2	111.
		20	28,800	4.290	59.3	78.9	111.	167.
		30	43,200	6.435	126.	167.	234.	354.
		40	57,600	8.580	214.	285.	399.	603.
		60	86,400	12.870	454.	603.	846.	1279.
		80	115,200	17.160	773.	1028.	1441.	2178.
1½	1.610	4	5,760	0.630	1.42	1.89	2.65	4.01
		5	7,200	.788	2.15	2.86	4.00	6.06
		6	8,640	.946	3.01	4.01	5.62	8.49
		8	11,520	1.261	5.13	6.82	9.57	14.5
		10	14,400	1.576	7.76	10.3	14.5	21.9
		12	17,280	1.891	10.9	14.5	20.3	30.6
		16	23,040	2.521	18.5	24.6	34.5	52.2
		20	28,800	3.152	28.0	37.2	52.2	78.9
		30	43,200	4.728	59.3	78.9	111.	167.
		50	72,000	7.880	153.	203.	285.	431.
		75	108,000	11.820	324.	431.	603.	912.
		100	144,000	15.759	551.	734.	1028.	1554.
		125	180,000	19.699	833.	1109.	1554.	2350.
2	2.067	6	8,640	0.574	0.802	1.19	1.66	2.51
		8	11,520	765	1.52	2.02	2.83	4.28
		10	14,400	956	2.30	3.06	4.28	6.47
		12	17,280	1.147	3.22	4.28	6.00	9.07
		16	23,040	1.530	5.48	7.30	10.2	15.5
		20	28,800	1.912	8.29	11.3	15.5	23.3
		30	43,200	2.868	17.6	23.4	32.8	49.5
		50	72,000	4.781	45.2	60.2	84.3	128.
		75	108,000	7.171	95.8	128.	179.	270.
		100	144,000	9.561	163.	217.	304.	460.
		150	216,000	14.342	346.	460.	645.	975.
		200	288,000	19.122	589.	784.	1099.	1661.

Pipe size inches	Inside diameter inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
2½	2.469	8	11,520	0.536	0.639	0.733	0.851	1.19
		10	14,400	.670	.966	1.11	1.29	1.80
		12	17,280	.804	1.35	1.55	1.80	2.53
		16	23,040	1.072	2.31	2.65	3.07	4.30
		20	28,800	1.340	3.49	4.00	4.64	6.51
		25	36,000	1 675	5.27	6.05	7.02	9.83
		50	72,000	3.351	19.0	21.8	25.3	35.5
		100	144,000	6.701	68.7	78.8	91.4	128.
		150	216,000	10.052	146.	167.	194.	271.
		200	288,000	13.402	248.	284.	330.	462.
		250	360,000	16.753	375.	430.	499.	699.
		300	432,000	20.103	526.	603.	699.	980.
3	3.068	10	14,400	0.434	0.336	0.385	0.446	0.626
		15	21,600	.651	.711	.816	.946	1.33
		20	28,800	.868	1.21	1.39	1.61	2.26
		25	36,000	1.085	1.83	2.10	2.44	3.41
		50	72,000	2.170	6.61	7.58	8.79	12.3
		100	144,000	4.340	23.9	27.4	31.7	44.5
		200	288,000	8.680	86.1	98.8	115.	161.
		300	432,000	13.020	182.	209.	243.	340.
		400	576,000	17.360	311.	357.	414.	580.
		500	720,000	21.699	470.	539.	625.	876.
3½	3.548	10	14,400	0 325	0.165	0.190	0.220	0.308
		15	21,600	.487	.350	.402	.466	.653
		20	28,800	.649	.597	.684	.794	1.11
		25	36,000	.811	.902	1.03	1.20	1.68
		50	72,000	1.623	3.26	3.73	4.33	6.07
		100	144,000	3.245	11.8	13.5	15.6	21.9
		200	288,000	6.490	42.4	48.7	56.4	79.1
		300	432,000	9.735	89.9	103.	120.	168.
		400	576,000	12.980	153.	176.	204.	286.
		500	720,000	16.225	231.	266.	308.	432.
		600	864,000	19.470	324.	372.	432.	605.
4	4.026	20	28,800	0.504	0.322	0.370	0.420	0.601
		25	36,000	.630	.487	.559	.648	.909
		30	43,200	.756	.683	.784	.909	1.27
		40	57,600	1.008	1.16	1.33	1.55	2.17
		50	72,000	1.260	1.76	2.02	2.34	3.28
		100	144,000	2.520	6.35	7.28	8.45	11.8
		200	288,000	5.040	22.9	26.3	30.5	42.7
		300	432,000	7.561	48.6	55.7	64.6	90.6
		400	576,000	10.081	82.7	94.9	110.	154.
		500	720,000	12.601	125.	143.	166.	233.
		600	864,000	15.121	175.	201.	233.	327.
		800	1,152,000	20.162	299.	343.	397.	557.

Pipe size inches	Inside diameter inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
5	5.047	30	43,200	0.481	0.227	0.261	0.302	0.424
		40	57,600	.642	.387	.441	.515	.722
		50	72,000	.802	.585	.671	.779	1.09
		100	144,000	1.604	2.11	2.42	2.81	3.94
		200	288,000	3.208	7 63	8.75	10.1	14.2
		300	432,000	4.812	16.2	18.5	21.5	30.1
		400	576,000	6.416	27.5	31.6	36.6	51.3
		500	720,000	8.020	41.6	47 7	55.3	77.6
		750	1,080,000	12.030	88.2	101.	117.	164.
		1000	1,440,000	16.040	150.	172.	200.	280.

Pipe size inches	Inside diameter inches	Discharge in Gallons per 24 hours	Discharge in Cubic feet per second	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
6	6.065	50,000	0.0774	0.386	0.122	0.140	0.162	0.227
		60,000	0.928	.463	.171	.196	.227	.318
		80,000	.124	.617	.291	.333	.387	.542
		100,000	.155	.771	.439	.504	.585	.819
		200,000	.309	1.542	1.59	1.82	2.11	2.96
		300,000	.464	2.314	3.36	3 85	4.47	6.27
		400,000	.619	3.085	5.72	6.57	7.62	10.7
		600,000	.928	4.627	12.1	13.9	16.1	22.6
		800,000	1.238	6.170	20.7	23.7	27.5	38.5
		1,000,000	1.547	7.712	31.2	35.8	41.6	58.2
		1,500,000	2.321	11.568	66.2	75.9	88.1	123.
		2,000,000	3.094	15.424	113.	129.	150.	210.
8	7.981	200,000	0.309	0.891	0.416	0.478	0.554	0.777
		300,000	.464	1.336	.882	1.01	1.17	1.65
		400,000	.619	1.781	1.50	1.72	2.00	2.80
		500,000	.774	2.227	2.27	2.61	3.02	4.24
		750,000	1.160	3.340	4.82	5.52	6.41	8.98
		1,000,000	1.547	4.454	8.20	9.41	10.9	15.3
		1,500,000	2.321	6.680	17.4	19.9	23.1	32.4
		2,000,000	3.094	8.907	29.6	34.0	39.4	55.2
		3,000,000	4.642	13.361	62.7	72.0	83.5	117.
10	10.020	300,000	0.464	0.848	0.291	0.334	0.388	0.543
		400,000	.619	1.130	.496	.569	660	.926
		500,000	.774	1.413	.750	.861	.998	1.40
		750,000	1.160	2.119	1.59	1.82	2.12	2.96
		1,000,000	1.547	2.825	2.71	3.11	3.60	5.05
		2,000,000	3.094	5.651	9.78	11.2	13.0	18.2

Pipe size inches	Inside diameter inches	Discharge in Gallons per 24 hours	Discharge in Cubic feet per second	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
10	10.020	3,000,000	4.642	8.476	20.7	23.8	27.6	38.6
		4,000,000	6.189	11.302	35.3	40.5	47.0	65.8
		5,000,000	7.736	14.127	53.4	61.2	71.0	99.5
12	12.000	300,000	0.464	0.591	0.121	0.139	0.161	0.226
		400,000	.619	.788	.206	.237	.274	.385
		500,000	.774	.985	.312	.358	.415	.581
		1,000,000	1.547	1.970	1.13	1.29	1.50	2.10
		1,500,000	2.321	2.955	2.38	2.74	3.17	4.45
		2,000,000	3.094	3.940	4.06	4.66	5.40	7.58
		3,000,000	4.642	5.910	8.61	9.87	11.5	16.1
		5,000,000	7.736	9.850	22.2	25.4	29.5	41.3
		7,500,000	11.60	14.775	47.0	53.9	62.5	87.6
		10,000,000	15.47	19.700	80.0	91.8	106.	149.
14 O D	13.250	500,000	0.774	0.808	0.192	0.221	0.256	0.359
		1,000,000	1.547	1.616	.695	.797	.924	1.30
		2,000,000	3.094	3.232	2.51	2.88	3.34	4.68
		3,000,000	4.642	4.847	5.31	6.09	7.07	9.91
		5,000,000	7.736	8.079	13.7	15.7	18.2	25.5
		7,500,000	11.60	12.119	29.0	33.3	38.6	54.1
		10,000,000	15.47	16.158	49.4	56.6	65.7	92.1
		12,500,000	19.34	20.198	74.7	85.6	99.3	139.
16 O D	15.250	750,000	1.160	0.915	0.206	0.236	0.274	0.383
		1,000,000	1.547	1.220	.350	.402	.466	.653
		2,000,000	3.094	2.440	1.26	1.45	1.68	2.36
		3,000,000	4.642	3.659	2.68	3.07	3.56	5.00
		5,000,000	7.736	6.099	6.90	7.91	9.18	12.9
		7,500,000	11.60	9.148	14.6	16.8	19.4	27.3
		10,000,000	15.47	12.198	24.9	28.6	33.1	46.4
		15,000,000	23.21	18.297	52.8	60.5	70.2	98.4
18 O D	17.182	1,000,000	1.547	.961	0.196	0.225	0.261	0.365
		2,000,000	3.094	1.922	.707	.811	.941	1.32
		3,000,000	4.642	2.883	1.50	1.72	1.99	2.79
		5,000,000	7.736	4.805	3.86	4.43	5.13	7.20
		7,500,000	11.60	7.207	8.18	9.38	10.9	15.2
		10,000,000	15.47	9.609	13.9	16.0	18.5	26.0
		15,000,000	23.21	14.414	29.5	33.9	39.3	55.0
		20,000,000	30.94	19.218	50.3	57.7	66.9	93.8
20 O D	19.182	1,000,000	1.547	0.771	0.115	0.131	0.152	0.214
		2,000,000	3.094	1.542	.414	.475	.550	.771
		3,000,000	4.642	2.313	.876	1.01	1.17	1.63
		5,000,000	7.736	3.855	2.26	2.59	3.00	4.21
		7,500,000	11.60	5.782	4.78	5.49	6.36	8.92
		10,000,000	15.47	7.710	8.15	9.35	10.8	15.2
		15,000,000	23.21	11.565	17.3	19.8	23.0	32.2
		20,000,000	30.94	15.419	29.4	33.7	39.1	54.8

Table 16

Loss of Head in Pipe by Friction for Large Diameter Pipe Listed by I. D. Sizes, Calculated by Hazen-Williams Formula

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Million gallons per 24 hours	Cubic feet per second		c=140	c=130	c=120	c=100
22	1.8333	1	1.547	0.586	0.059	0.067	0.078	0.110
		2.5	3.868	1.465	.321	.368	.427	.598
		5	7.736	2.931	1.16	1.33	1.54	2.16
		7.5	11.60	4.396	2.45	2.81	3.26	4.57
		10	15.47	5.861	4.18	4.79	5.56	7.79
		15	23.21	8.792	8.86	10.2	11.8	16.5
		20	30.94	11.722	15.1	17.3	20.1	28.1
		25	38.68	14.653	22.8	26.2	30.3	42.5
24	2.0000	2	3.094	0.985	0.139	0.159	0.185	0.259
		5	7.736	2.462	.758	.869	1.01	1.41
		7.5	11.60	3.694	1.61	1.84	2.14	2.99
		10	15.47	4.925	2.74	3.14	3.64	5.10
		15	23.21	7.387	5.80	6.65	7.71	10.8
		20	30.94	9.850	9.87	11.3	13.1	18.4
		25	38.68	12.312	14.9	17.1	19.9	27.8
		30	46.42	14.775	20.9	24.0	27.8	39.0
26	2.1667	2	3.094	0.839	0.094	0.108	0.125	0.175
		5	7.736	2.098	.513	.589	.683	.957
		7.5	11.60	3.147	1.09	1.25	1.45	2.03
		10	15.47	4.196	1.85	2.12	2.46	3.45
		15	23.21	6.295	3.93	4.50	5.22	7.32
		20	30.94	8.393	6.69	7.67	8.90	12.5
		25	38.68	10.491	10.1	11.6	13.4	18.8
		30	46.42	12.589	14.2	16.3	18.8	26.4
28	2.3333	2	3.094	0.724	0.066	0.075	0.087	0.122
		5	7.736	1.809	.358	.410	.476	.667
		7.5	11.60	2.714	.758	.869	1.01	1.41
		10	15.47	3.618	1.29	1.48	1.72	2.41
		15	23.21	5.428	2.74	3.14	3.64	5.10
		20	30.94	7.237	4.66	5.35	6.20	8.69
		25	38.68	9.046	7.05	8.08	9.37	13.1
		30	46.42	10.855	9.88	11.3	13.1	18.4
30	2.5000	5	7.736	1.576	0.256	0.293	0.340	0.477
		10	15.47	3.152	.923	1.06	1.23	1.72
		15	23.21	4.728	1.96	2.24	2.60	3.65
		20	30.94	6.304	3.33	3.82	4.43	6.21
		25	38.68	7.880	5.03	5.78	6.70	9.39
		30	46.42	9.456	7.06	8.10	9.39	13.2
		35	54.15	11.032	9.39	10.8	12.5	17.5
		40	61.89	12.608	12.0	13.8	16.0	22.4
36	3.0000	5	7.736	1.094	0.105	0.121	0.140	0.196
		10	15.47	2.189	.380	.436	.505	.708
		15	23.21	3.283	.804	.923	1.07	1.50
		20	30.94	4.378	1.37	1.57	1.82	2.56
		30	46.42	6.567	2.90	3.33	3.86	5.41
		40	61.89	8.756	4.95	5.67	6.58	9.22
		50	77.36	10.944	7.48	8.58	9.95	13.9
		60	92.83	13.133	10.5	12.0	13.9	19.5

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Million gallons per 24 hours	Cubic feet per second		c=140	c=130	c=120	c=100
42	3.50	5	7.736	0.804	0.050	0.057	0.066	0.093
		10	15.47	1.608	.179	.206	.238	.334
		15	23.21	2.412	.380	.436	.505	.708
		20	30.94	3.216	.647	.742	.861	1.21
		30	46.42	4.824	1.37	1.57	1.82	2.56
		40	61.89	6.433	2.34	2.68	3.11	4.35
		50	77.36	8.041	3.53	4.05	4.70	6.58
		75	116.0	12.061	7.48	8.58	9.95	13.9
48	4.00	5	7.736	0.616	0.026	0.030	0.034	0.048
		10	15.47	1.231	.094	.107	.124	.174
		20	30.94	2.462	.338	.387	.449	.630
		30	46.42	3.694	.715	.821	.952	1.33
		40	61.89	4.925	1.22	1.40	1.62	2.27
		50	77.36	6.156	1.84	2.11	2.45	3.44
		75	116.0	9.234	3.90	4.48	5.19	7.28
		100	154.7	12.312	6.65	7.63	8.85	12.4
54	4.50	10	15.47	0.973	0.053	0.060	0.070	0.098
		20	30.94	1.946	.190	.218	.253	.355
		30	46.42	2.919	.403	.462	.536	.752
		40	61.89	3.891	.687	.788	.913	1.28
		50	77.36	4.864	1.04	1.19	1.38	1.94
		75	116.0	7.296	2.20	2.52	2.93	4.10
		100	154.7	9.728	3.75	4.30	4.98	6.99
		125	193.4	12.160	5.66	6.50	7.54	10.6
60	5.00	10	15.47	0.788	0.032	0.036	0.042	0.059
		20	30.94	1.576	.114	.131	.151	.212
		30	46.42	2.364	.241	.277	.321	.450
		40	61.89	3.152	.411	.471	.547	.766
		50	77.36	3.940	.621	.713	.827	1.16
		75	116.0	5.910	1.32	1.51	1.75	2.45
		100	154.7	7.880	2.24	2.57	2.98	4.18
		125	193.4	9.850	3.39	3.89	4.51	6.32
66	5.50	10	15.47	0.651	0.020	0.023	0.026	0.037
		20	30.94	1.302	.072	.082	.095	.133
		30	46.42	1.954	.152	.174	.202	.283
		50	77.36	3.256	.391	.448	.520	.728
		75	116.0	4.884	.828	.949	1.10	1.54
		100	154.7	6.512	1.41	1.62	1.88	2.63
		125	193.4	8.140	2.13	2.44	2.84	3.97
		150	232.1	9.769	2.99	3.43	3.97	5.57
72	6.00	10	15.47	0.547	0.013	0.015	0.017	0.024
		25	38.68	1.368	.071	.081	.094	.132
		50	77.36	2.736	.256	.293	.340	.477
		75	116.0	4.104	.542	.621	.721	1.01
		100	154.7	5.472	.923	1.06	1.23	1.72
		125	193.4	6.840	1.40	1.60	1.86	2.60
		150	232.1	8.208	1.96	2.24	2.60	3.65
		175	270.8	9.576	2.60	2.98	3.46	4.85

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Cubic feet per second	Million gallons per 24 hours		c=140	c=130	c=120	c=100
78	6.50	25	16.16	0.753	0.021	0.025	0.028	0.040
		50	32.32	1.507	.077	.089	.103	.144
		75	48.47	2.260	.163	.188	.217	.305
		100	64.63	3.014	.278	.319	.371	.519
		150	96.95	4.520	.590	.677	.785	1.10
		200	129.3	6.027	1.01	1.15	1.34	1.87
		250	161.6	7.534	1.52	1.74	2.02	2.83
		300	193.9	9.041	2.13	2.44	2.83	3.97
84	7.00	25	16.16	0.650	0.015	0.017	0.020	0.028
		50	32.32	1.299	.054	.062	.072	.100
		75	48.47	1.949	.114	.131	.152	.212
		100	64.63	2.598	.194	.223	.258	.362
		150	96.95	3.898	.411	.472	.547	.767
		200	129.3	5.197	.701	.804	.932	1.31
		250	161.6	6.496	1.06	1.22	1.41	1.98
		300	193.9	7.795	1.48	1.70	1.98	2.77
90	7.50	25	16.16	0.566	0.011	0.012	0.014	0.020
		50	32.32	1.132	.038	.044	.051	.072
		75	48.47	1.698	.081	.093	.108	.152
		100	64.63	2.264	.139	.159	.185	.259
		150	96.95	3.395	.294	.337	.391	.548
		200	129.3	4.527	.501	.574	.666	.934
		300	193.9	6.791	1.06	1.22	1.41	1.98
		400	258.5	9.054	1.81	2.07	2.40	3.37
96	8.00	25	16.16	0.497	0.008	0.009	0.010	0.014
		50	32.32	0.995	.028	.032	.037	.052
		100	64.63	1.989	.101	.116	.135	.189
		150	96.95	2.984	.215	.246	.286	.400
		200	129.3	3.979	.366	.419	.486	.682
		300	193.9	5.968	.775	.889	1.03	1.44
		400	258.5	7.958	1.32	1.51	1.76	2.46
		500	323.2	9.947	2.00	2.29	2.65	3.72

The Scobey Formula

Fred C. Scobey,* Senior Irrigation Engineer of the Division of Agricultural Engineering, U. S. Department of Agriculture, offers the following formulas which he says "include viscosity influence for a temperature of 15° C. (59° F.) and differentiate between various types and classes of sheet and plate metal pipe by means of coefficients, which are themselves constant throughout the whole range of sizes and velocities for a given class of pipe":

$$hf = \frac{K_s v^{1.9}}{D^{1.1}}$$

$$v = \frac{hf^{.526} D^{.58}}{K_s^{.526}}$$

where hf = Loss of head in feet due to friction per 1000 feet of pipe.
D = Mean inside diameter of pipe in feet.
v = Mean velocity of the water in feet per second.
K_s = General coefficient. (K'_s is this value for new pipe.)

Scobey limited his study to pipe of nominal size, four inch and larger, and assumed that the interior of all pipe would be chemically protected with a coating which would form the true interior surface, at least during the first years of the life of the conduit.

He divides sheet and plate metal pipe into three major classes:

Class 1—"Full-riveted" pipe, having both longitudinal and girth seams held by one or more lines of rivets with projecting

*United States Department of Agriculture Technical Bulletin No. 150 "The Flow of Water in Riveted Steel and Analogous Pipes" (1930).

Table 17
Loss of Head in Pipe by Friction for National Duroline Pipe*
Calculated by the Hazen-Williams Formula

Pipe size, inches	Average inside diameter, inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (hf) ($c = 148$)
½	0.484	1	1,440	1.74	35.0
		2	2,880	3.48	126.0
		3	4,320	5.23	265.0
		4	5,760	6.97	455.0
		5	7,200	8.72	685.0
		6	8,640	10.46	970.0
		8	11,520	13.95	1650.0
		10	14,400	17.44	2500.0
¾	0.686	2	2,880	1.73	22.8
		3	4,320	2.60	48.0
		4	5,760	3.47	82.0
		5	7,200	4.34	124.0
		6	8,640	5.21	173.0
		8	11,520	6.94	295.0
		10	14,400	8.68	443.0
		15	21,600	13.02	946.0
		20	28,800	17.36	1590.0
1	0.896	3	4,320	1.52	13.2
		4	5,760	2.03	22.2
		5	7,200	2.54	34.5
		6	8,640	3.05	47.5
		8	11,520	4.07	81.0
		10	14,400	5.08	120.0
		12	17,280	6.10	170.0
		14	20,160	7.12	225.0
		16	23,040	8.14	290.0
		20	28,800	10.16	432.0
		25	36,000	12.70	630.0
		30	43,200	15.24	925.0
1¼	1.175	4	5,760	1.18	5.8
		5	7,200	1.47	9.0
		6	8,640	1.77	12.6
		7	10,080	2.07	16.7
		8	11,520	2.36	21.5
		10	14,400	2.95	32.5
		12	17,280	3.55	45.5
		14	20,160	4.14	59.0
		16	23,040	4.73	77.0
		18	25,920	5.32	96.0
1¼	1.175	20	28,800	5.91	116.0
		25	36,000	7.39	175.0
		30	43,200	8.87	245.0
		40	57,600	11.80	420.0
		60	86,400	17.70	880.0
1½	1.405	4	5,760	0.82	2.60
		5	7,200	1.03	3.95
		6	8,640	1.24	5.28
		7	10,080	1.44	7.3
		8	11,520	1.65	9.4
		9	12,960	1.86	11.6
		10	14,400	2.06	14.2
		12	17,280	2.48	19.8
		14	20,160	2.89	26.4
		16	23,040	3.31	34.5
		18	25,920	3.72	42.0
		20	28,800	4.13	51.0
		22	31,680	4.55	61.0
		24	34,560	4.96	72.0
		26	37,440	5.38	83.0
		28	40,320	5.79	95.0
		30	43,200	6.20	108.0
		35	50,400	7.24	135.0
		40	57,600	8.27	176.0
		50	72,000	10.34	266.0
		75	108,000	15.51	562.0
		100	144,000	20.69	960.0
2	1.780	6	8,640	0.77	1.66
		8	11,520	1.03	2.82
		10	14,400	1.28	4.30
		12	17,280	1.54	6.0
		14	20,160	1.80	8.0
		16	23,040	2.06	10.2
2	1.780	18	25,920	2.32	12.7
		20	28,800	2.57	15.5
		25	36,000	3.22	23.2
		30	43,200	3.86	33.0
		35	50,400	4.51	44.0
		40	57,600	5.15	56.0
		45	64,800	5.80	77.0
		50	72,000	6.44	84.0
		55	79,200	7.09	100.0
		60	86,400	7.73	117.0
		65	93,600	8.37	135.0
		70	100,800	9.02	157.0
		75	108,000	9.66	177.0
		100	144,000	12.89	302.0
		150	216,000	19.33	570.0
2½	2.182	8	11,250	0.68	1.05
		10	14,400	.85	1.58
		12	17,280	1.02	2.25
		16	23,040	1.37	3.85
		25	36,000	2.14	8.6
		50	72,000	4.29	31.5
		100	144,000	8.58	113.0
		150	216,000	12.87	240.0
		200	288,000	17.16	410.0
		250	360,000	21.45	620.0
3	2.725	10	14,400	0.55	0.54
		15	21,600	.82	1.15
		20	28,800	1.10	1.95
		25	36,000	1.37	2.95
		50	72,000	2.75	10.6
		80	115,200	4.40	25.3
		100	144,000	5.50	38.5
		160	230,400	8.80	90.0
		200	288,000	11.00	136.0
		300	432,000	16.50	290.0
		400	576,000	22.00	500.0
		500	720,000	27.50	750.0
3½	3.205	10	14,400	0.39	0.24
		15	21,600	.59	.52
		20	28,800	.79	.88
		25	36,000	.99	1.34
		50	72,000	1.98	4.8
		80	115,200	3.18	11.5
		100	144,000	3.97	17.5
		160	230,400	6.36	41.5
		200	288,000	7.95	63.0
		300	432,000	11.93	135.0
		400	576,000	15.90	225.0
		500	720,000	19.88	340.0
4	3.620	20	28,800	0.62	0.49
		25	36,000	.77	.74
		30	43,200	.93	1.04
		50	72,000	1.55	2.68
		80	115,200	2.49	6.4
		100	144,000	3.11	9.7
		160	230,400	4.98	23.4
		200	288,000	6.23	35.0
		300	432,000	9.35	72.2
		400	576,000	12.46	124.0
		500	720,000	15.58	187.0
5	4.548	30	43,200	0.59	0.34
		40	57,600	.79	.58
		50	72,000	.98	.87
		80	115,200	1.58	2.10
		100	144,000	1.97	3.15
		160	230,400	3.16	7.7
		200	288,000	3.95	11.5
		300	432,000	5.92	24.2
		400	576,000	7.90	41.2
		500	720,000	9.87	61.8
		750	1,080,000	14.81	131.0
6	5.440	50,000	.0774	0.47	0.20
		60,000	.0928	.57	.26
		80,000	.1238	.76	.44
		100,000	.1547	.95	.66
		140,000	.2166	1.34	1.25
		200,000	.3094	1.91	3.42
		300,000	.4642	2.87	5.2
		400,000	.619	3.83	8.7
		500,000	.774	4.79	13.2
		600,000	.928	5.75	18.5
6	5.440	800,000	1.238	7.67	31.5
		1,000,000	1.547	9.58	48.0
		1,500,000	2.321	14.37	100.0
		2,000,000	3.094	19.17	170.0
8	7.446	200,000	.3094	1.02	0.53
		300,000	.4642	1.53	1.12
		360,000	.557	1.84	1.57
		400,000	.619	2.04	1.92
		500,000	.774	2.55	2.88
		600,000	.928	3.06	4.05
		700,000	1.083	3.58	5.4
		800,000	1.238	4.09	6.9
		900,000	1.392	4.60	8.6
		1,000,000	1.547	5.11	10.5
		1,200,000	1.857	6.13	14.6
		1,500,000	2.321	7.67	22.0
		2,000,000	3.094	10.23	37.0
		3,000,000	4.642	15.34	79.0
8	7.356	200,000	.3094	1.04	0.56
		300,000	.4642	1.57	1.18
		400,000	.619	2.09	2.00
		500,000	.774	2.62	3.05
		600,000	.928	3.14	4.30
		700,000	1.083	3.66	5.7
		800,000	1.238	4.19	7.3
		1,000,000	1.547	5.24	11.2
		1,500,000	2.321	7.86	23.8
		2,000,000	3.094	10.48	40.0
		3,000,000	4.642	15.72	84.0
10	9.443	300,000	.4642	0.95	0.35
		400,000	.619	1.27	.60
		500,000	.774	1.59	.90
		600,000	.928	1.90	1.26
		750,000	1.160	2.38	1.92
		1,000,000	1.547	3.18	3.25
		1,500,000	2.321	4.77	6.9
		2,000,000	3.094	6.36	11.8
		3,000,000	4.642	9.54	25.0
		4,000,000	6.188	12.72	42.5

*Pipe lined with a highly resistant cement-base composition lining.—Ed.

heads. From the capacity standpoint, pipe with countersunk rivet heads on the interior belong in *Class* 3.

Class 2—"Girth-riveted" pipe, having no retarding rivet heads in the longitudinal seams, but having the same girth seams as full-riveted pipe.

Class 3—"Continuous-interior" pipe, having the interior surface unmarred by plate offsets or by projecting rivet heads in either longitudinal or girth seams. Not necessarily described as "smooth."

For these classes Scobey suggests the following coefficients for new pipe:

Class 1*a*, $K'_s = 0.38$ for new sheet metal pipe up to three-sixteenths of an inch thick.

Class 1*b*, $K'_s = 0.44$ for new plate metal pipe on three-sixteenths to seven-sixteenths of an inch thick, with either taper or cylinder joints.

Class 1*c*, $K'_s = 0.48$ for new plate metal pipe from one-half inch up, with either taper or cylinder joints, and for plate from one-fourth to seven-sixteenths of an inch thick when butt-jointed.

Class 1*d*, $K'_s = 0.52$ for new butt-strap pipe of plate from one-half inch up.

Class 2*d*, $K'_s = 0.34$ for new girth-riveted pipe. This includes all sheet and plate metal pipe with continuous seamed lognitudinal joints but with girth joints, particularly field joints, made with the usual rivet heads inside the pipe.

Class 3, $K'_s = 0.32$ for new continuous-interior pipe. This class comprises all type of sheet and plate metal pipe that offer a practically uniform interior surface of relative smoothness. "Continuous-interior" is offered as descriptive of an interior surface unbroken by rivet heads or appreciable shell-thickness offsets. Use of the apparently obvious synonym "smooth" has purposely been avoided, as this description might hold only while the pipe is new.

NOTE: Although Scobey confines his paper to the discussion of sheet and plate metal pipe, *Classes* 2 and 3 also apply to seamless pipe as well as to lap-weld, hammer-weld, and electric-weld pipe.

It should be noted that the coefficients (K'_s) given above

are for new pipe. Concerning the deterioration of carrying capacity with age, Scobey states:

> "It has long been appreciated that all metal pipe deteriorates in carrying capacity; the rate of decrease being dependent on the efficiency of the pipe coating, the composition and treatment of the pipe material, and the activity of the water conveyed in the pipe. Filtered and treated water causes less deterioration than raw water. Long lines deteriorate more rapidly at the upper ends than at the lower ends.
> "So far as available data indicate, the increase in the value of K_s with age, is expressed by the formula:
>
> $$K_s = K'_s e^{0.032t}$$
>
> where e = Base of Naperian logarithms (2.7183).
> t = Age of pipe in years.
> When t is zero, then K_s becomes K'_s."

[NOTE: Tables showing various values of K_s and corresponding losses of head at various velocities and also values of $v^{1.9}$ have had to be omitted. For a copy of these address National Tube Co., Pittsburgh, Pa., asking for Technical Bulletin No. 21. —Ed.]

Fig. 36, which was taken from United States Department of Agriculture Technical Bulletin No. 150, will be found useful in making estimates and preliminary studies. It gives the relation between discharge, pipe diameter, velocity, and loss of head for various values of the coefficient K_s. Values of K_s for ages of 0 to 50 years corresponding to various values of K'_s are also given.

The lower age diagram on the chart is based on the formula $K_s = K'_s e^{0.032t}$ and is to be used for aggressive waters. The upper age diagram is based on the formula $K_s = K'_s e^{0.01t}$ and is intended for use where the waters are known to be non-aggressive.

The following example will illustrate the method of using this chart:

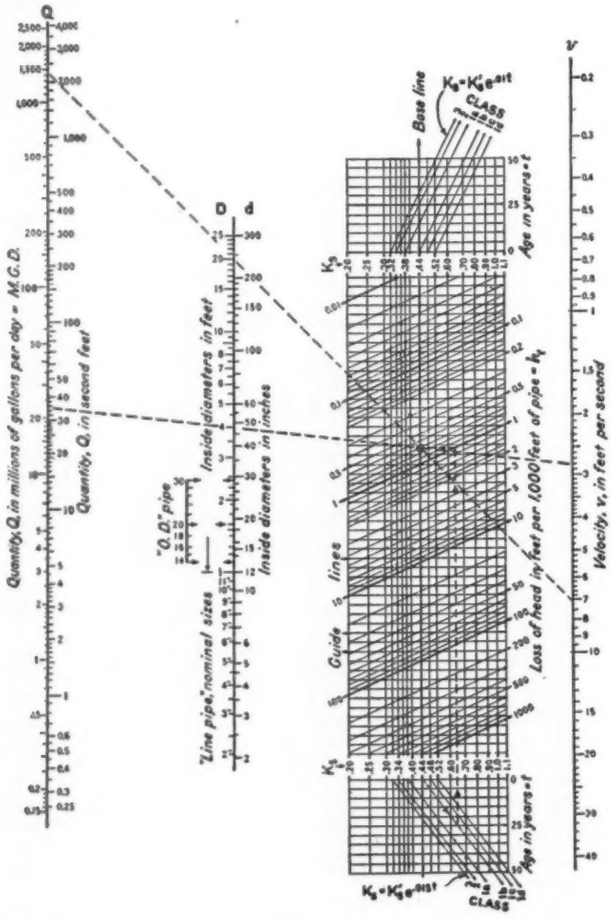

Fig. 36 — Chart Showing Relation Between Discharge Pipe Diameter, Velocity, and Loss of Head for Various Values of the Coefficient K_s and K_{s1} in Scobey Formula

Table 21

Special Losses of Head in Terms of $v^2/2g$ (From Hydraulics, by Ernest W. Schoder and Francis M. Dawson—Second Edition, 1934, with Modifications)

Nature of special resistance	Loss of head as decimal or multiple of $v^2/2g$*
Entrance	
Square-edged entry. Upstream end of pipe perpendicular to, and flush with inside face of reservoir wall	0.50
Projecting pipe at entry or re-entrant pipe end	1.00
Well-rounded entry	0.02 to 0.05
Curves and Fittings	
Easy curves or bends of very large radius, and smooth inside, of same inside diameter throughout as the pipe line. Excess loss over same length of straight pipe	0.05 to 0.15
90-degree curves, fairly smooth, same inside diameter as pipe; Radius of center line = diameter of pipe	0.50
Radius of center line = 2 to 8 times diameter of pipe	0.25
90-degree common screw end pipe elbows, short turn, inside larger than pipe	0.75
Tees, common screw end, full-size branch, flow deviated 90 degrees	1.50
Square elbow (intersection of two cylinders, corner not rounded at outside or inside of curve.)	1.25
Obtuse-angled elbows, (deflection of pipe less than 90 degrees); multiply values for square elbow or 90-degree curve by $\left(\frac{\text{deflection, degrees}}{90 \text{ degrees}}\right)^2$	
Water Meters (Subject to much variation)	
Disk or "wobble-disk" type	3.4 to 10
Rotary type (star or cog-wheel-shaped disk as piston)	10
Reciprocating piston type (like a piston pump)	15
Turbine-wheel type (double flow, balanced)	5 to 7.5
Diaphragm and Orifice Meters	
Diaphragm of thin material across pipe, with concentric hole, or an inside projecting washer or gasket, or a "burr", due to cutting pipe with a wheel cutter: Diameter of hole = 0.91 × diameter of pipe	0.34
Diameter of hole = 0.80 × diameter of pipe	1.88
(Note that $v^2/2g$ in this particular case refers to pipe, not to the area of opening, nor to the contracted stream through opening.)	
Nozzles	
Nozzles: when the coefficient of velocity and discharge ranges from 0.99 to 0.975, the loss of head ranges from	0.02 to 0.05 (Where v is the velocity of the issuing jet)

*Note: Except where otherwise noted, v is the mean velocity in the pipe.

Assume that it is desired to know what conditions will prevail in a pipe line constructed of full-riveted pipe (*Class* 1*b*) after carrying aggressive waters for a period of 25 years.

From page 45 the coefficient K_s for new pipe of *Class* 1*b* is found to be 0.44. On the lower age diagram follow the diagonal line representing $K_s = 0.44$ (at 0 age) until it intersects the horizontal line representing an age of 25 years. From this point of intersection proceed vertically on the dashed line (which represents $K_s = 0.64$) until it intersects the slope line of 1 foot per 1000 feet of pipe. From this point follow the guide lines to the vertical base line. Using this point (marked on the chart by a circle) as a pivot, a straight edge will give simultaneous values of discharge (Q) diameter (D or d) and velocity (v). This is illustrated by dashed lines for 20 feet and 4 feet inside diameter pipe. The dashed line through the pivot point and the point representing pipe of 20 feet inside diameter shows that a discharge of 2250 cubic feet per second and a velocity of 7.2 feet per second can be expected. The other dashed line through the pivot point and through the point representing pipe 4 feet inside diameter indicates a discharge of 36 cubic feet per second and a velocity of 2.8 feet per second.

Special Losses of Head

Curves, elbows, tees, meters, enlargements, contractions, etc., in a pipe line cause losses of head, which, if of consequence, must be allowed for in addition to the loss of head ordinarily encountered in straight pipe of uniform cross section.

Special losses may be expressed as equivalent lengths of straight pipe which would cause the same loss of head, or as decimals or multiples of $v^2/2g$, where v is the mean velocity in the pipe. For any particular special fittings, experiments show that the loss of head is not in all cases a constant fraction of

Table 21—Concluded

Special Losses of Head in Terms of $v^2/2g$

Nature of special resistance	Loss of head as decimal or multiple of $v^2/2g$*
Venturi Meter Tubes	
Venturi meter tubes: the loss of head occurs mostly in and downstreamwards from the divergence, the loss between upstream end and throat being only 0.03 to 0.06$\times v^2/2g$, where v is the throat velocity. The total loss through the meter is:	
For total angle of divergence $= \pm 5$ degrees	$\frac{1}{7}$ to $\frac{1}{10}$ Where v is the throat velocity
For total angle of divergence $= \pm 15$ degrees	$\frac{1}{3}$ to $\frac{1}{6}$
(The lower values go with large throats, and the larger values with small throats whose diameter is from ⅕ to ½ the diameter of the pipe.)	
Sudden Enlargement	
Sudden enlargement, from a small pipe ending abruptly where a larger pipe begins, is found to involve loss of head fairly close in accordance with Borda's Formula which is: Loss of head $= \frac{(v_1 - v_2)^2}{2g}$ (Note that this is not the difference of the velocity heads, but is the head corresponding to the difference of the velocities.) The above-stated formula may be written: Loss of head $= \left(1 - \frac{A_1}{A_2}\right)^2 \frac{v_1^2}{2g}$, or for a circular or square pipe: Loss of head $= \left[1 - \left(\frac{d_1}{d_2}\right)^2\right]^2 \times \frac{v_1^2}{2g}$ where A_1, v_1 and d_1 refer to the smaller upstream pipe, while the subscript 2 refers to the larger downstream pipe.	
Sudden Square-Edged Reductions	
Sudden square-edged reductions in pipes. When the sudden reduction of pipe is very large, say $d_2/d_1 = 0.1$, the loss of head is practically as given for square-edged entry, i.e., loss of head $= 0.40\, v_2^2/2g$. For smaller reductions the value of K is smaller, but the experimental data of Weisbach (1855) and Brightmore (1907) do not agree. For ratios $d_2/d_1 =$ 0.5, 0.75, and 0.9 the value K is about 0.33, 0.20 and 0.08, respectively. In this case the subscript 2 refers to the smaller downstream pipe, and K is the factor which, multiplied by $v_2^2/2g$, gives the loss of head.	

*Note: Except where otherwise noted, the v is mean velocity in the pipe.

$v^2/2g$, but that the fraction varies somewhat with the velocity. For most practical purposes, however, the values given in 21 may be relied on as safe average values.

Water Hammer

When a valve in a water line is closed while the water is flowing, the velocity of the water upstream from the valve is reduced and a dynamic pressure is exerted in addition to the normal static pressure. This dynamic pressure, commonly called "water hammer," is the result of the transformation of the kinetic energy of the moving mass of water into pressure energy which expends itself (unless relief devices are provided) by compressing the water and stretching the pipe walls. When a valve is closed suddenly, the magnitude of the dynamic pressure produced is frequently much greater than the static pressure on the line, and may cause fracture of the pipe or fittings.

Starting at the suddenly-closed valve, a wave of increased pressure is transmitted back through the pipe with constant velocity and intensity. When the pressure wave has traveled upstream to the end of the pipe, where there is a reservoir or large main, the elasticity of the compounded water and of the expanded pipe reverse the flow and a wave of normal pressure travels downstream, the flow being progressively reversed as the water expands.

If the water were incompressible and the pipe inelastic, the instantaneous closure of the valve would create an infinite pressure. Since it is impossible to close a valve instantaneously, it is apparent that a series of pressure waves is created, causing an increased pressure at the valve. If the valve is completely closed before the first pressure wave has time to return to the valves as a wave of low pressure, the pressure increases continually up to the time of complete closure and the resulting pressure is just the same as if the valve had been instantaneously closed. The velocity of the pressure wave depends upon the ratio of wall-thickness to inside pipe diameter and on the modulus of elasticity of the water and of the pipe material according to the formula:

$$S = \frac{12}{\sqrt{\frac{w}{g}\left(\frac{1}{E_w} + \frac{d}{E_p t}\right)}}$$

The head due to water hammer in excess of normal static head is proportional to the destroyed velocity and to the velocity of the pressure wave along the pipe. Since the intensity of the excess head depends upon the destroyed velocity, the same excess pressure is produced by suddenly reducing the velocity from 6 to 3 feet per second, as by entirely stopping a velocity of 3 feet per second. The excess head due to water hammer is given by the formula:

$$h = \frac{12\, v}{g\sqrt{\frac{w}{g}\left(\frac{1}{E_w} + \frac{d}{E_p t}\right)}}$$

where S = Velocity of pressure wave along pipe in feet per second.
w = Weight of water in pounds per cubic foot.
h = Head due to water hammer (in excess of static head).
g = Acceleration of gravity.
t = Wall-thickness of pipe in inches.
d = Inside diameter of pipe in inches.
E_p = Modulus of elasticity of pipe material in pounds per square inch.
E_w = Modulus of elasticity of water in pounds per square inch.
v = Destroyed velocity in feet per second.

By inserting values for g, w, E_w and E_p the two formulas may be simplified. Thus, if
$g = 32.174$ feet per second per second.
$w = 62.4096$ pounds per cubic foot (at 50° F.)
$E_w = 300{,}000$ pounds per square inch.
$E_p = 29{,}000{,}000$ pounds per square inch (for steel pipe)
the formulas reduce to:

$$S = \frac{4720}{\sqrt{1 + .0103\frac{d}{t}}}$$

$$h = \frac{147\, v}{\sqrt{1 + .0103\frac{d}{t}}}$$

If the flow is not checked rapidly, so that the wave from the first movement of the valve has time to travel upstream to the end and back again several times while the valve closing is in progress, the excess pressure is greatly reduced. Therefore, it is advisable to use slow closing valves or to provide air chambers or surge tanks in the line to absorb the shock due to water hammer.

Measurement of Flowing Water

Pitot Tubes

Pitot tubes are used to measure the velocity of flowing water. Such a tube consists essentially of a vertical tube, the lower end of which is bent at 90° so that its open end is directed against the current. The velocity of the flowing water causes the water to rise in the vertical leg of the pitot tube a distance above the free surface of the stream equal to the velocity head.

When a pitot tube is inserted into a pipe carrying water under pressure, the water will rise in the vertical leg of the tube a distance equal to the sum of the pressure head and the velocity head at the point where the tube is inserted. If a piezometer tube is tapped into the wall of the pipe at substantially the same point, the water will rise in this tube a distance equal to the pressure head at that point. The difference in the levels of the water in the two tubes will therefore be equal to the velocity head in the pipe at the point where the tubes are inserted. Fig. 37 shows such an arrangement. The height of the water in the pitot tube is equal to the sum of the pressure head, h_p, and the velocity head, h_v. The height of the water in the piezometer tube is equal to the pressure head, h_p. The

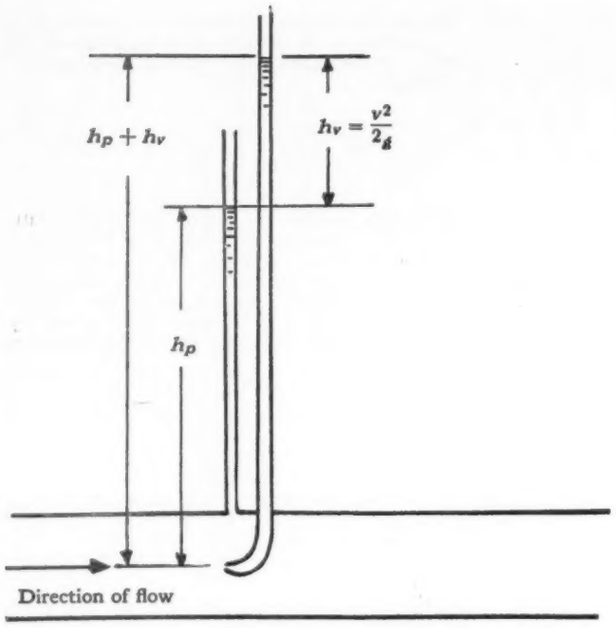

Fig. 37—Pitot Tube

difference in the height of the water in the two tubes is therefore equal to the velocity head, h_v.

Mercury columns or manometers may be used, instead of the water column, to determine the pressures.

In order to determine the discharge by use of a pitot tube, the cross section of the stream or pipe must be divided into one or more known areas, the velocity for each found, and hence the mean velocity of the entire cross section. The discharge is then found by multiplying the cross-sectional area by the mean velocity. In a straight length of pipe which extends upstream about 50 diameters from place of measurement without tees, valves, etc., the distribution of velocities is normal. Where normal distribution of velocities prevails, the ratio of mean velocity to center velocity (called the pipe coefficient) averages about 0.83.

Venturi Meters

The Venturi meter was invented by Clemens Herschel and was named by him for the inventor of the principle involved. It may be used to measure the discharge of water or other fluids contained in pipes which run full and under positive pressure.

The Venturi tube consists of a converging cone of steep taper, a diverging cone of more gradual taper, and a short cylindrical section called the throat, which connects the two cones at their smallest diameters. The essential parts of a Venturi meter are shown in Fig. 38. In this figure h_1 represents the pressure head in the pipe upstream for the Venturi meter, h_2 the pressure head at the throat, and h_3 the pressure head in the pipe downstream from the Venturi meter. The difference between h_1 and h_3 is hf and is the loss of head due to friction in the Venturi tube. The loss of head in a Venturi tube is usually quite small (see Table 21). Where the recovery of pressure is not important the converging cone may be very short or may even be omitted, forming a Venturi nozzle.

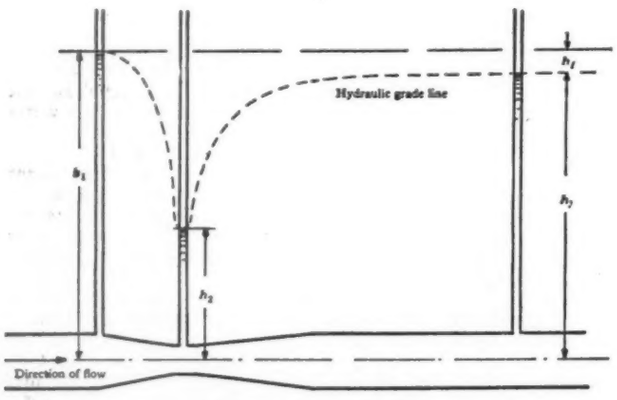

Fig. 38—Venturi Meter

Since the quantity of water flowing past any cross section of the tube is the same at any instant, the velocity at the small cross section of the throat will be greater than in the large cross section of the pipe upstream from the Venturi tube.

This greater velocity in the throat is obtained at the expense of the pressure head, so that h_2 is less than h_1. The dotted line in the figure represents the approximate hydraulic grade line and indicates the loss and recovery of pressure from h_1 to h_3.

The relation between the flow through a Venturi tube and the difference in pressure between the inlet and throat is given by the formula:

$$Q = C_v A_2 \sqrt{\frac{2ghd}{1-\left(\frac{A_2}{A_1}\right)^2}} = C_v A_2 \sqrt{\frac{2ghd}{1-\left(\frac{D_2}{D_1}\right)^4}}$$

where Q = Discharge in cubic feet per second.
D_1 = Inside diameter of pipe in feet.
D_2 = Inside diameter of throat of Venturi tube in feet.
A_1 = Cross-sectional area of inside of pipe in square feet.
A_2 = Cross-sectional area of inside of throat of tube in square feet.
g = Acceleration of gravity = 32.174 feet per second per second.
hd = Differential head in feet of water = $h_1 - h_2$.
C_v = Discharge coefficient of Venturi tube which varies from about 0.95 to 0.995.

The pressure differences $(h_1 - h_2)$ may be measured by a simple glass U-tube containing mercury. Commercial Venturi tubes are usually provided with two annular chambers connected by vents with the inlet and throat, respectively, to obtain correct average pressures at these points. Various types of indicating, recording and integrating meters may be obtained for use with commercial Venturi tubes.

Pipe Orifices

Orifices in diaphragms inserted between pairs of flanges in straight portions of pipe lines have been found to be reliable measuring devices. The diaphragms are usually of thin noncorrodible metal and the orifices are accurately machined to size and beveled on the downstream side to keep the working edge thin.

Fig. 39 shows the essential parts of such a device. Two piezometer tubes are attached to the line, one at a distance of

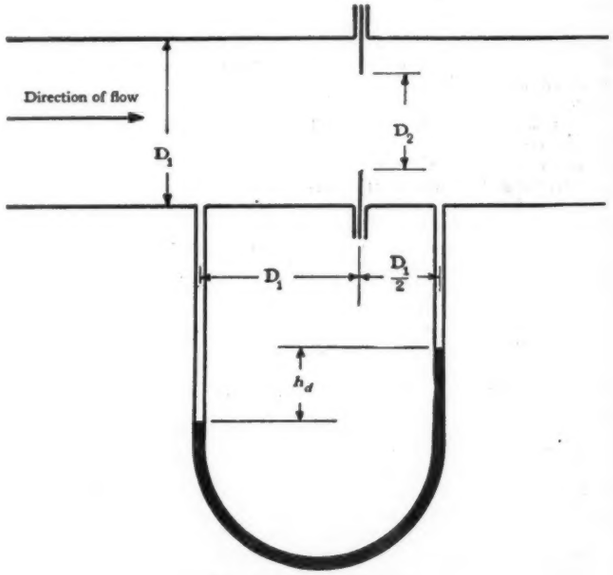

Fig. 39—Pipe Orifice

one pipe diameter upstream and the other one-half pipe diameter downstream from the plate. Either a differential gage, as shown in the figure, or open water columns may be used, depending upon the pressure. The rate of flow is a function of the differential pressure as indicated by the formula:

$$Q = C_o A_2 \sqrt{\frac{2ghd}{1-\left(\frac{A_2}{A_1}\right)^2}} = C_o A_2 \sqrt{\frac{2ghd}{1-\left(\frac{D_2}{D_1}\right)^4}}$$

where Q = Discharge in cubic feet per second.
D_1 = Inside diameter of pipe in feet.
D_2 = Diameter of orifice in feet.
A_1 = Cross-sectional area of inside of pipe in square feet.
A_2 = Cross-sectional area of orifice in square feet.
g = Acceleration of gravity = 32.174 feet per second per second.
hd = Differential head in feet of water = $h_1 - h_2$.
C_o = Discharge coefficient = about 0.606 for D_2/D_1 from 0.10 to 0.75.

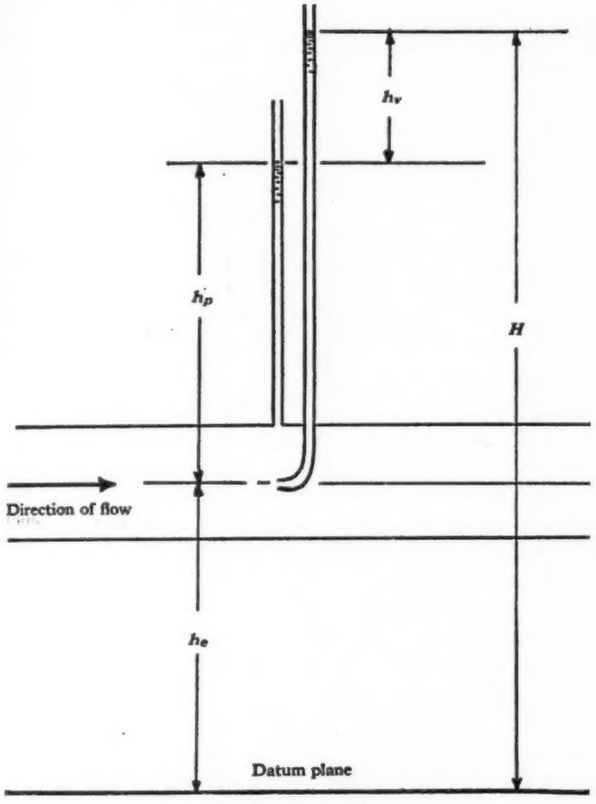

Fig. 40—Total Head

The orifice should be placed in a straight section of horizontal or vertical pipe and should be located as far as possible from bends, fittings, and valves. The diameter of the orifice should not be greater than 75 to 80 per cent of the inside diameter of the pipe. The loss of head in the pipe orifice is quite large and it is less reliable than the Venturi meter.

Water Power

The total available power of flowing water is given by the formula:

$$H.P. = \frac{QwH}{550} = 0.113472\,QH$$

where $H.P.$ = Horse Power.
Q = Discharge in cubic feet per second.
H = Total available head in feet.
w = Weight of one cubic foot of water (at 50° F. = 62.4096 pounds).

The total head may be made up of velocity head, pressure head, and potential head, or head due to actual height above the datum plane. Fig. 40 illustrates the three components of the total head.

The value of the velocity head is given by the expression:

$$h_v = \frac{v^2}{2g}$$

where h_v = Velocity head in feet.
v = Mean velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.

Table 22
Horsepower for Various Heads of Water

Horse power for 1 cu. ft. of water per second under heads of 1 to 2,000 ft. Based on an efficiency of 80 per cent and weight of water at 50°F. = 62.4096 lb. per cubic foot.

(Horse power per cubic foot of water per second = $\frac{62.4096 \times 0.80 \times H}{550} = 0.0907776\,H$).

Head in feet (H)	Horse power	Head in feet (H)	Horse power	Head in feet (H)	Horse power	Head in feet (H)	Horse power
1	0.0907776	170	15.4322	420	38.1266	925	83.9693
2	.181555	180	16.3400	430	39.0344	950	86.2387
3	.272333	190	17.2477	440	39.9421	975	88.5082
4	.363110	200	18.1555	450	40.8499	1000	90.7776
5	.453888	210	19.0633	460	41.7577	1050	95.3165
6	.544666	220	19.9711	470	42.6655	1100	99.8554
7	.635443	230	20.8788	480	43.5732	1150	104.394
8	.726221	240	21.7866	490	44.4810	1200	108.933
9	.816998	250	22.6944	500	45.3888	1250	113.472
10	.907776	260	23.6022	525	47.6582	1300	118.011
20	1.81555	270	24.5100	550	49.9277	1350	122.550
30	2.72333	280	25.4177	575	52.1971	1400	127.089
40	3.63110	290	26.3255	600	54.4666	1450	131.628
50	4.53888	300	27.2333	625	56.7360	1500	136.166
60	5.44666	310	28.1411	650	59.0054	1550	140.705
70	6.35443	320	29.0488	675	61.2749	1600	145.244
80	7.26221	330	29.9566	700	63.5443	1650	149.783
90	8.16998	340	30.8644	725	65.8138	1700	154.322
100	9.07776	350	31.7722	750	68.0832	1750	158.861
110	9.98554	360	32.6799	775	70.3526	1800	163.400
120	10.8933	370	33.5877	800	72.6221	1850	167.939
130	11.8011	380	34.4955	825	74.8915	1900	172.477
140	12.7089	390	35.4033	850	77.1610	1950	177.016
150	13.6166	400	36.3110	875	79.4304	2000	181.555
160	14.5244	410	37.2188	900	81.6998	....	.....

Table 25—Pressure Equivalents

Units		Pounds per square inch	Pounds per square foot	Kilograms per square centimeter	Inches of mercury at 32° F.	Feet of water at 39.2° F.	Feet of water at 62° F.	Atmospheres
1 pound per square inch	=	1.	144.	0.0703067	2.0360	2.30671	2.30934	0.068044
1 pound per square foot	=	0.0069444	1.	0.0004882	0.014139	0.016019	0.016037	0.0004725
1 ounce per square inch	=	0.0625	9.	0.0043942	0.12725	0.144169	0.144334	0.0042528
1 kilogram per square centimeter	=	14.2234	2048.17	1.	28.9582	32.8092	32.8467	0.967820
1 kilogram per square meter	=	0.0014223	0.204817	0.0001	0.0028958	0.0032809	0.0032847	9.678×10^{-5}
1 inch of mercury at 32° F.	=	0.49117	70.7285	0.034533	1.	1.13299	1.13428	0.033421
1 inch of water at 39.2° F.	=	0.036127	5.20222	0.0025399	0.073552	0.083333	0.083428	0.0024582
1 inch of water at 62° F.	=	0.036085	5.19628	0.0025370	0.073468	0.083238	0.083333	0.0024554
1 foot of water at 39.2° F.	=	0.43352	62.4266	0.030479	0.88262	1.	1.00114	0.029498
1 foot of water at 62° F.	=	0.43302	62.3554	0.030444	0.88162	0.99886	1.	0.029465
1 atmosphere	=	14.6963	2116.27	1.03325	29.9210	33.9001	33.9388	1.

Table 26—Rate of Flow Equivalents

Units		Cubic feet per second	Cubic feet per minute	U. S. gallons per minute	U. S. gallons per 24 hours	British Imperial gallons per minute	Liters per minute	Acre-feet per hour	Acre-feet per 24 hours
1 cubic foot per second	=	1.	60.	448.831	646 317.	373.729	1698.98	0.082645	1.98347
1 cubic foot per minute	=	0.016667	1.	7.48052	10 771.9	6.22882	28.3163	0.0013774	0.033058
1 U. S. gallon per minute	=	0.0022280	0.13368	1.	1440.	0.83267	3.78533	0.0001841	0.0044192
1 U. S. gallon per 24 hours	=	1.547×10^{-6}	9.283×10^{-5}	0.0006944	1.	0.0005782	0.0026287	1.279×10^{-7}	3.069×10^{-6}
1 British Imperial gallon per minute	=	0.0026757	0.16054	1.20095	1729.37	1.	4.54601	0.0002211	0.0053072
1 liter per minute	=	0.0005886	0.035315	0.26418	380.416	0.21997	1.	4.864×10^{-5}	0.001167
1 acre-foot per hour	=	12.1	726.	5430.86	7 820 434.	4522.13	20 557.6	1.	24.
1 acre-foot per 24 hours	=	0.50417	30.25	226.286	325 851.	188.422	856.567	0.041667	1.

Table 26—Volume and Capacity Equivalents

Units		United States gallons	British Imperial gallons	Liters	Cubic feet	Cubic inches	Acre-feet
1 United States gallon	=	1.	0.832672	3.78533	0.133681	231.	3.069×10^{-6}
1 British Imperial gallon	=	1.20095	1.	4.54601	0.160544	277.420	3.686×10^{-6}
1 liter	=	0.264177	0.219973	1.	0.035315	61.0250	8.107×10^{-7}
1 cubic foot	=	7.48052	6.22882	28.3163	1.	1728.	2.296×10^{-5}
1 cubic inch	=	4.329×10^{-3}	3.605×10^{-3}	0.016387	5.787×10^{-4}	1.	1.329×10^{-8}
1 acre-foot	=	325 851.	271 328.	1 233 456.	43 560.	75 271 680.	1.
1 inch deep on 1 acre	=	27 154.3	22 610.6	102 788.	3 630.	6 272 640.	0.083333
1 inch deep on 1 square mile	=	17 378 743.	14 470 801.	65 784 344.	2 323 200.	4 014 489 600.	53.3333
1 meter deep on 1 hectare	=	2 641 705.	2 199 675.	9 999 734.	353 145.	610 233 780.	8.10708
1 centimeter deep on 1 square meter	=	2.64171	2.19967	9.99973	0.353145	610.234	8.107×10^{-6}
1 pound of water at 39.2° F.	=	0.11983	0.099778	0.45359	0.016019	27.6805	3.677×10^{-7}
1 pound of water at 50° F.	=	0.11986	0.099806	0.45372	0.016023	27.6880	3.678×10^{-7}
1 pound of water at 62° F.	=	0.11997	0.099892	0.45411	0.016037	27.7121	3.682×10^{-7}
1 U. S. gallon per minute for 24 hours	=	1440.	1199.05	5450.88	192.5	332 640.	0.0044192
1 cubic foot per minute for 24 hours	=	10 771.9	8 969.50	40 775.4	1440.	2 488 320.	0.033058

The pressure head is given by the expression:

$$h_p = \frac{P}{w}$$

where h_p = Pressure head in feet.
P = Pressure in pounds per square foot.

The potential head or head due to height above the datum plane is h_e feet.

The total head, H, is therefore:

$$H = h_v + h_p + h_e$$

or

$$H = \frac{v_2}{2g} + \frac{P}{w} + h_e$$

In any stream flowing steadily without friction, the total head, and the total amount of energy per unit of water, is the same at every point in the path of flow. This principle, which is in reality the law of conservation of energy applied to flowing water, is known as Bernoulli's Theorem.

Table 22 gives the horse power for one cubic foot of water per second, under heads of 1 to 2000 feet, based on an efficiency of 80 per cent. The method of using this table is illustrated by the following example:

Determine the horse power which can be developed by a flow of 60 cubic feet per second under a head of 200 feet.

From the table the horse power for a discharge of one cubic foot per second under 200 feet head is found to be 18.1555. The horse power for a discharge of 60 cubic feet per second under 200 feet head is then:

$$60 \times 18.1555 = 1089.33 \text{ horse power.}$$

When the exact head is not given in the table the horse power may be found by multiplying the horse power for one foot head and one cubic foot per second (0.0907776) by the head in feet and then by the discharge in cubic feet per second. For example, the horse power which can be developed by a discharge of 45 cubic feet per second under a head of 105 feet will be:

$$0.0907776 \times 105 \times 45 = 428.92 \text{ horse power.}$$

PRACTICAL HYDRAULICS*

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I. The Sharp Crest Weir

The so called Sharp Crest Weir is a very useful device for the measurement of water flowing in open channels or streams. A knowledge of the few simple rules governing the design and use of weirs will make it possible to measure the flow of water shed streams contributing to reservoirs, to estimate the overflow or leakage of dams and to make other measurements of use to the water works operator.

By a Weir is meant a bulkhead or dam over which the water flows, or more particularly, a notch in the top of such a structure through which the water flows. As shown in the illustration (Fig. 1), it usually consists of a rectangular notch and it is then known as a Rectangular Weir.

The Crest of a weir is the bottom of the notch, the level to which the water must rise before any can flow over. It is the edge or sill over which the water flows. A weir is a Sharp Crest Weir when the bottom edge of the notch, or the crest, is constructed so as to be as sharp as possible, flush with the upstream face of the dam, and with the opening beveled or enlarged on the downstream side so that the stream of water as it passes through the opening will only touch the crest along one sharp edge, as shown in Fig. 2. In the laboratory the crest is kept as sharp as a knife edge. In practice the edge of a metal plate or angle iron, as shown in the illustration, is usually satisfactory unless extreme accuracy is desired. The upstream face of the weir should be vertical, and of course the crest should be exactly horizontal.

The Head on a weir is the difference in elevation between the crest of the weir and the surface of the water in the pool upstream from the weir. With any given weir there is a fixed relation between the head and the amount of water being discharged, thus by measuring the head the discharge may be determined from the formula or table which applies to that particular form of weir in use.

The relation between the head and the discharge of a weir is different with different forms of crest and different shapes of notches. Different formulas must be used with such different weirs. The reason for making a weir sharp crested is that by so doing a weir can be built which can be used for the measurement of water without the necessity for making special tests to determine what the formula is. The formula for rectangular sharp crest weirs is known, and it has been found easier to reproduce standard conditions by the use of the sharp crest design than with most other forms. Most weirs built for the measurement of water are therefore constructed as sharp crest weirs.

Weir Formulas

One of the most commonly used formulas for use with rectangular sharp crest weirs is known as the Francis formula, named for its originator, Mr. J. B. Francis, who performed extensive experiments on weirs at Lowell, Mass., in 1851. This formula is as follows:

$$Q = 3.33 \times L \times h \times \sqrt{h}$$

In this formula:—

Q = Discharge of the weir in cubic feet per second.
L = Length of the weir crest in feet.
h = Head on the weir in feet.
$\sqrt{h}$ = The square root of the head in feet. The square root of the head is the number which, multiplied by itself, equals the head.

($h \times \sqrt{h}$ is often expressed as $h^{3}/^{2}$, but it is more readily computed if considered in the form given above.)

Example: A sharp crest rectangular weir is 5.00 feet long and has a head of 0.42 feet (5 inches) on it.

(The square root of 0.42 is 0.65, because $0.65 \times 0.65 = 0.42$.)

$Q = 3.33 \times 5.00 \times 0.42 \times 0.65 = 4.55$ cu. ft. per second.

The Francis formula given above is most accurate for heads between about 0.30 feet and 2.00 feet. A small error in determining the head makes such a large error in the discharge at very low heads, that for most practical purposes this formula is sufficiently accurate at all heads up to about 2.00 feet, and it is fairly accurate for higher heads also. The great advantage of the Francis formula is the fact that it is much simpler to compute than most of the others. The principal other formulas are known as the Bazin formula, the Fteley and Stearns formula and the Rehbock formula. A complete treatise may be referred to for the details of these other formulas.

For convenience the results of the computations from a weir formula may be arranged in a table, as shown in Table I. The discharge read from the table may be multiplied by the length (in feet) of any sharp crest weir to obtain the discharge.

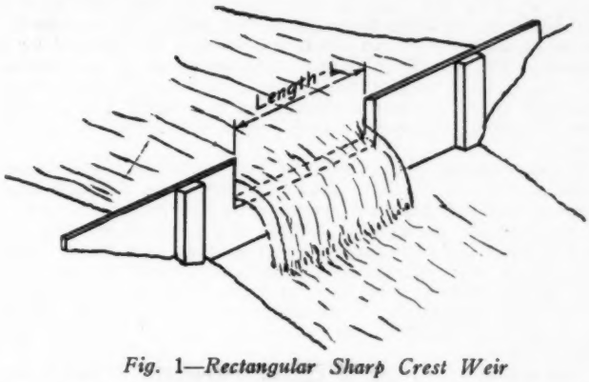

Fig. 1—Rectangular Sharp Crest Weir

TABLE I—DISCHARGE OF A SHARP CREST WEIR PER FOOT OF LENGTH BY THE FRANCIS FORMULA

Head Expressed in Feet	Head Expressed in Inches	Discharge per Foot of Length of Weir Expressed in Cubic Feet per Second	Discharge per Foot of Length of Weir Expressed in Gallons per Minute
.01	1/8	.0033	1.5
.02	1/4	.0094	4.2
.03	3/8	.0173	7.8
.04	1/2	.0266	11.9
.05	5/8	.0372	16.7
.06	3/4	.049	22.0
.07	7/8	.062	27.7
.08	1	.075	33.8
.09	1 1/8	.090	40.4
.10	1 1/4	.105	47.2
.12	1 1/2	.138	62.
.14	1 5/8	.175	78.
.16	1 7/8	.213	96.
.18	2 1/8	.254	114.
.20	2 3/8	.298	134.
.22	2 5/8	.344	155.
.24	2 7/8	.392	176.
.26	3 1/8	.441	198.
.28	3 3/8	.49	222.
.30	3 5/8	.55	246.
.32	3 7/8	.60	271.
.34	4 1/8	.66	296.
.36	4 3/8	.72	323.
.38	4 1/2	.78	350.
.40	4 3/4	.84	378.
.42	5	.91	407.
.44	5 1/4	.97	436.
.46	5 1/2	1.04	467.
.48	5 3/4	1.11	497.
.50	6	1.18	530.
.55	6 5/8	1.36	610.
.60	7 1/4	1.55	690.
.65	7 3/4	1.75	780.
.70	8 3/8	1.95	870.
.75	9	2.16	970.
.80	9 5/8	2.38	1070.
.85	10 1/4	2.61	1170.
.90	10 3/4	2.84	1270.
.95	11 3/8	3.08	1380.
1.00	12	3.33	1500.

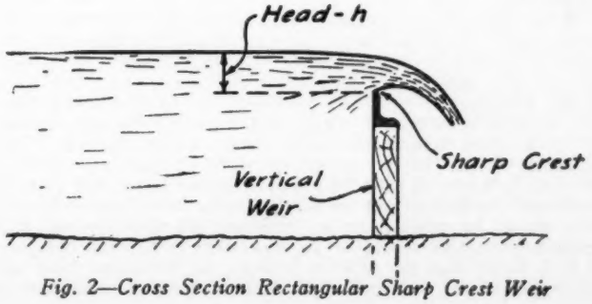

Fig. 2—Cross Section Rectangular Sharp Crest Weir

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II. The End Contractions of a Weir

There are two methods of constructing the ends of the weir. The first of these is shown in Fig. 3 and results in what is known as a weir *with end contractions.* In this design the sharp crest of the weir as formed by the bottom of the notch is continued up the ends of the notch, thus forming sharp edged ends for the weir. The water in flowing around these sharp corners then follows a course very similar to that taken in flowing over the edge of a sharp crest. In flowing around the edge from behind the weir it cannot change direction sharply and it curves inward toward the center of the weir contracting the stream as shown in the illustration.

The other method of designing the ends of the notch is to build it so that it extends the full width of the stream at that point, allowing the sides of the channel to form the ends of the notch and continue upstream at that width for a short distance, at least. An example of this method of construction is shown in Fig. 4. When so built it is known as a weir *without end contractions* because the water in this case flows straight over the crest, the stream continuing full width all the way. The weir thus consists of a simple dam or bulkhead across the channel.

It may readily be seen that if two rectangular sharp crest weirs have the same length and are flowing under the same head, the one that has end contractions (Fig. 3) is not discharging as much water as the weir without end contractions (Fig. 4). It has been found by experimentation that with sharp edged ends and a wide channel above the weir, so that the over-falling stream is fully contracted, the effect on the discharge of the weir is the same as if the length of the weir were reduced by a distance equal to one-tenth (0.1) of the head at each end of the weir.

For example: A sharp crested, rectangular, vertical weir is three feet long and the ends are so constructed that the flow will be fully contracted. If the head is one foot, then the effective length of the weir is reduced by one-tenth of a foot at each end making its effective length $(3.0 - 0.2) = 2.8$ feet—a reduction in capacity of about 7 per cent from the capacity it would have had without end contractions. Failure to make this correction might constitute a rather serious error.

If the head on the same 3 foot weir were only 0.1 foot instead of 1.0 foot (or if the length of the weir were increased to 30 feet with a head of 1.0 feet) then in either case the reduction in effective length would be only about 0.7 per cent which

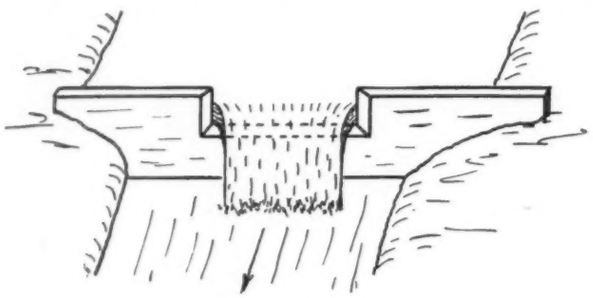

Fig. 3—Weir with End Contractions

would be a negligible error except in the most precise measurements.

It is thus seen that the importance of making the correction for end contractions depends upon the relative head and the length of the weir. If the head is more than one twentieth (5 per cent) of the length then end contractions will require a correction of more than 1 per cent and should certainly be accounted for.

Weirs are seldom operated in practice under a head sufficiently great in proportion to the length that the correction for end contractions is of importance. In such cases it is evident that it does not matter how the ends of the weir are built. Many weirs under practical conditions are built so that they do not have theoretically sharp edged ends and yet neither are they ended against the sides of the stream channel. The ends may merely be formed by the wood or masonry of which the dam bulkhead is built. In such cases we know that there is some end contraction but we do not know how much. Such a weir should be checked up to determine whether the end contraction correction would be of importance if it were complete. If it is found that the relation between the maximum head and the length of the weir is such that the correction would not be

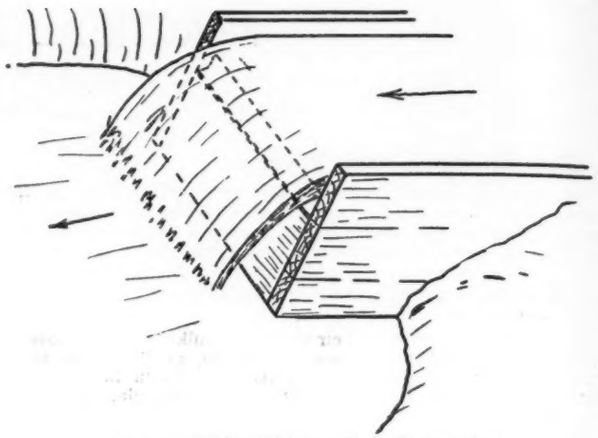

Fig. 4—Weir Without End Contractions

of importance (less than 1 per cent), then we know that it does not matter what it actually is and it can be neglected. It is found that the end contraction correction is of importance then either it must be estimated or else actual measurements of the flow must be made to determine what the correction actually should be. Usually it can be estimated. It is a help in estimating to actually observe the form of the stream during discharge of the weir.

If the relation between the length of the weir and the head is to be such that the end contraction correction will be of importance then the weir should, if possible, be built either with full contractions or with none at all so that the correction will be definitely known.

A weir may be built with a sharp edge on one end only so that the end has a full contraction and so that the other end has no contraction. The correction in such a case is, of course, only one-tenth of the head to be subtracted from the weir length.

III. Measurement of Head on Weirs

The measurement of flowing water by means of a weir depends in turn upon the measurement of the *head* of water on the weir. Having determined the weir formula to be used, depending upon the design of the weir crest, the presence or absence of end contractions and any other fixed condition, the recorded flow then depends upon the head. The head is the single remaining variable quantity. It is the quantity which is actually observed and measured in the field, the desired knowledge as to the amount of water flowing being then computed by the use of the formula, table or diagram. It is assumed in this discussion that the flow over the weir is not affected by backwater from below.

The head on a weir is the difference in elevation between the crest of the weir and the surface of the water in the pool upstream from the weir. Figure 1 is a vertical cross section through a sharp crest weir with water flowing over it under a head indicated by (h). The shape of the upper and lower water surfaces shown in this figure have been determined by measurement and have been found to have forms similar to these, regardless of what the head is, so long as the weir has a sharp crest and a vertical upstream face. Under special conditions at low heads the water may, however, cling to the downstream face of the weir.

Figure 1 shows clearly the fact that in this general case the

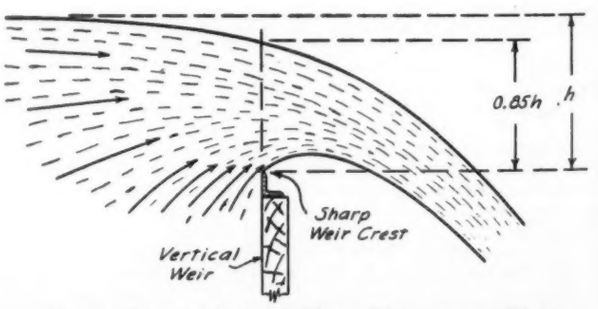

Fig. 1—Characteristics of Water Flow Over a Weir

water only touches the crest along the one sharp edge and then leaps free. The arrows showing the converging stream indicate the reason for the shape which the lower surface of the water is found to take. There is one very important fact to be noted from Figure 1—namely, the upper surface of the water starts to curve downward before it reaches the weir. This results in the depth of water at the weir crest actually being only about 85/100ths of "h" (expressed as 0.85h)—the condition which makes it necessary to measure the height of the water surface at some distance upstream from the weir when determining the head. The height of the water surface should be measured at a point located upstream from the weir *a distance at least equal to three times the maximum head* to be encountered.

Measuring Gages

The type and design of gage to be used to determine the water level depends upon the accuracy desired and the conditions under which it will operate.

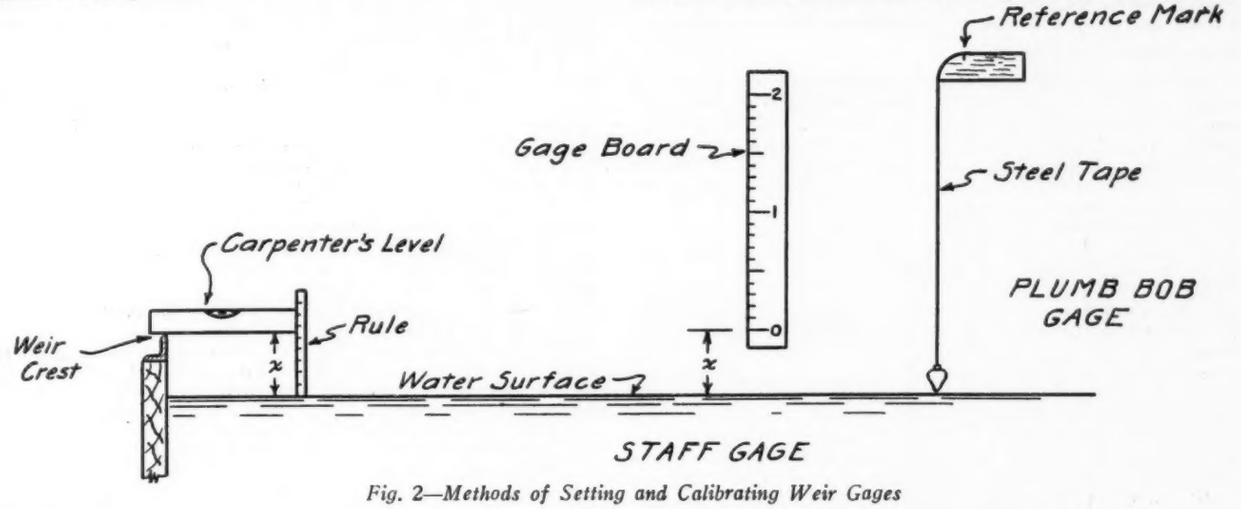

Fig. 2—Methods of Setting and Calibrating Weir Gages

The Staff-Gage

The simplest and most commonly used type of gage consists merely of a strip of wood or metal with the necessary graduations marked upon it. A section of a carpenter's rule or a surveyor's rod may be used if adequately waterproofed by varnishing. One of the best forms of gage board consists of a vitreous enameled ware metal plate mounted on a wood plank. The graduations and figures are baked into the enamel. Gages such as these, often called staff-gages, if well graduated and carefully read will enable the water level to be determined to within about 0.01 feet, equivalent to about ⅛ inch. This is sufficiently accurate for most purposes other than studies requiring laboratory refinements. One of the greatest disadvantages of this type of gage, however, is the necessity for locating the observer's eye near the water level when taking a reading. This is not always convenient. Care must be taken to read at the true water surface and not the height to which the water surface curves upwards where it wets the gage.

When mounting a staff-gage great care is needed to insure that the zero of the gage is exactly level with the crest of the weir and that it remains so. A small error in this respect will cause a large error in the results, particularly at low heads. Moreover, this error will always be in the same direction and will not tend to correct itself or be compensated for by other errors.

By the careful use of a surveyor's level a gage may be set with sufficient accuracy. If a surveyor's level is not available then the water surface itself may be used in the manner indicated in Figure 2. Choose a time when the water surface is not rising or falling too rapidly and preferably when it is lower than the weir crest. By means of a carpenter's hand level and rule measure the distance (x) down to the water surface from the weir crest. Then measure up from the water surface at the gage location and set the gage zero the same distance (x) above the water level as the weir crest was found to be. Then, afterward, such gages should be regularly checked to be certain that they have not been moved, and that the zero point is correct.

Plumb-Bob Gage

Another form of gage is known as a plumb-bob gage. It consists of a graduated steel tape with a heavy plumb bob on its end. It is used to measure from a fixed reference mark, above water level, down to the water surface. By allowing it to swing slightly the contact of the plumb bob with the water surface may be very accurately noted. This naturally assumes the water surface to be smooth. The plumb-bob gage may be most accurately read if the tape is run over a curved block of wood, mounted permanently above the water, which has the reference mark fixed on its upper surface, as indicated in Figure 2. The zero reading on this type of gage may be determined by measuring down to the water surface from the weir crest as shown in Figure 2 and applying the correction factor determined by a simultaneous reading of the tape.

Chain Gage

A similar type of gage known as a chain gage is often used. For the tape a chain running over a wheel is substituted. With this arrangement the position of a marker attached to the chain above the wheel is read along a horizontal scale. This type of gage is not so accurate as the former and it is not advised for weir readings except in the case of rough work or high heads. It is often used for river heights where accuracy within about 0.05 feet is generally satisfactory.

With all types of gages difficulty is introduced if the water level is disturbed by waves or surges. In the case of the gages above described this can only be overcome by the skill and patience of the operator in mentally averaging the indications while observing them over a short period. Practice can develop considerable skill in doing this.

IV. The Float Gage

Probably the most accurate type of gage, if well designed and constructed, is a float gage. Besides its accuracy it also has other advantages. Difficulty in reading due to waves and surges may be most readily overcome with the float type gage which is readily adapted to the use of an automatic recording mechanism. They may be classified into two types. The simplest type consists of the float with a rigid vertical stem attached to and supported by the float, with an index or pointer at its upper end. The gage reading is obtained from the position of this pointer along a fixed vertical scale. In the other type of float gage the motion of the float is transmitted to some form of indicating or recording mechanism by means of a flexible wire or tape.

The Float

A suitable float is the first essential. It must not become water logged, but must retain its buoyancy. To meet this condition a hollow sheet metal float is generally used, and copper is the preferred material because of its resistance to corrosion. The seams must be well locked and thoroughly soldered. Earthenware floats have been used in sewage or other corrosive liquids. Floats are most often made cylindrical with the axis vertical, in order to fit in a float pipe and. for ease of construction. It is important to have the top and bottom dished outward so that the float cannot be weighted with water on top or lifted by air trapped beneath. The float should have at least three vertical fins projecting a half inch or more from its sides in order to prevent it from clinging to the wall of the float pipe or well. Sometimes a spherical float is used, but in that case its weight, or its counterweight, should be adjusted so that it will float near its middle, in order to gain the maximum sensitivity.

Float Pipe

Floats are usually provided with some form of float pipe or stilling well. This serves two principal purposes—it serves as a guide for the float, and by adjusting the size of the communicating opening into the float pipe the effect of waves or surges upon the gage readings may be reduced. The use of a float pipe also makes it possible to locate the gage a short distance away from the body of water being observed, the level in the float pipe being maintained by a small size connecting pipe. With such an arrangement care must be exercised to avoid air traps in the connecting pipe. The connecting pipe should be made of non-corrosive material and should be provided with convenient means for flushing it out. A float pipe should be provided with a cover, having only a small opening for the wire or tape, in order to prevent objects from falling in and lodging on the float.

If the gage mechanism is light and easily operated, a 5-in. diameter float in a 6-in. float pipe makes a good combination. If a high degree of sensitivity is desired, or if a recorder requiring some power to operate it is used, then a larger float is desirable, a 10-in. float in a 12-in. pipe, or even larger, being often used.

Gage With Rigid Stem

The type of float gage having a rigid stem is the simplest and is also probably capable of the closest reading with accuracy, since the only friction involved in its motion is due to whatever guides may be needed to keep the stem upright and in the correct position with relation to the scale. The effect of this friction in preventing accurate response of the gage to changes in the water level may be largely if not entirely avoided by gently tapping the stem while reading the gage. Gages of this type, if properly designed and constructed, may be read directly to the nearest one thousandth of a foot (0.001 ft.), which is about the best in true accuracy that can be expected from single readings of any type of gage.

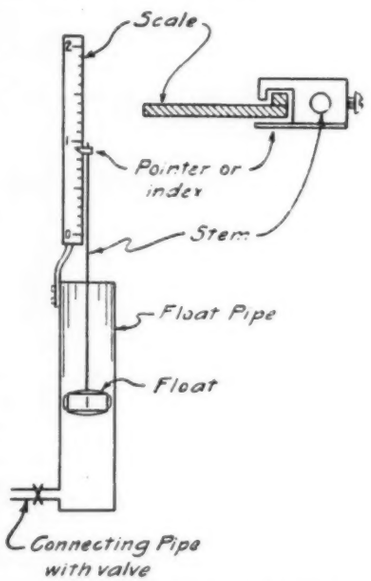

Fig. 1—Float Gage with Stem

An arrangement of this type of gage, which has been used extensively and which is highly suitable for accurate weir head readings, is shown in Fig. 1. In this design a 7-in. float may be used in an 8-in. float pipe. The float stem is a brass rod of about 3/16 in. or ¼ in. diameter, depending on the height. The best scale is made from a graduated brass strip about ⅛ in. thick. It is provided with a continuous projection along its back edge which serves to guide the index or pointer in the correct position for easy reading, and to hold the stem vertically above the float.

Gage With Flexible Wire

The second type of float gage, using a flexible wire or tape, is more adaptable to different arrangements, since the motion is usually converted into a rotary motion by the wheel or drum on which the wire is wound, and thus the readings may be shown on a circular dial, or a recording mechanism may be operated. It is not always so simple to overcome the friction of motion in this type of gage, and for that reason it may not be read quite so accurately unless the float is larger than with the rigid stem type.

A metal wire or tape is necessary for accurate readings in order to avoid changes in length due to stretching or moisture. The wire should be stranded, made from a large number of very small wires braided together, in order to be flexible and withstand frequent bending. Either wire or tape must be of bronze or other non-rusting metal.

The simplest arrangement of this type of gage consists merely of passing the wire over a wheel or pulley and having a counterweight on the end. Reading may then be taken from the motion of a pointer attached to the wire along a fixed vertical scale beside it. A very crude form of such a gage has often been seen on railroad water tanks.

A more usual arrangement in water works practice is to attach the end of the float wire to a drum, around which it is then wound a number of turns. The counterweight is then hung from another wire similarly attached to the drum. By such design slipping of the wire is avoided and the revolution of the drum is a true measure of the change in water level. The drum is then connected to a rotating pointer on a dial or to a recording device. By introducing suitable gearing a wide range of float motion may be shown as only a part of a revolution of the pointer on the dial, or other variations may be introduced changing the scale of readings to suit the conditions and the requirements.

The drum upon which the wire is wound should be provided with spiral grooves to receive the wire so that it will be guided in a single layer and will not wind upon itself, thereby changing the effective diameter of the drum and affecting the accuracy of the gage. If desired, the drum receiving the counterweight wire may be smaller than the drum for the float wire, thereby resulting in a shorter travel for the counterweight where this is of any advantage. The counterweight should not become submerged, since its effective weight would thereby be altered and the submersion of the float changed.

Gage With Tape

If a tape is used it is customary to provide it with uniformly spaced perforations which fall over similarly spaced projecting pins on the drum, thereby preventing slipping. A tape is, of course, not wound around the drum, but merely passes over it once, with the counterweight on the end. The counterweight must then travel through the same range of motion that the float does.

Indicators and Recorders

Many good designs of indicating and recording instruments are commercialy available for use with floats and which are adaptable to different conditions and requirements. Floats may also be utilized similarly to operate transmitters for long distance electrical transmission of gage readings, known as telemeters.

BAILEY METER COMPANY

1072 Ivanhoe Road, CLEVELAND, OHIO

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BAILEY METER COMPANY LIMITED, Montreal, Canada

METERS, GAGES and CONTROLLERS for SEWAGE TREATMENT and WATER SUPPLY

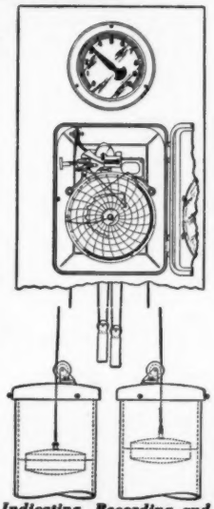
STANDARD BAILEY REGISTERS

Open Float Type Meters—The flow of sewage, sludge, dirty water or other liquids in pipe lines is accurately measured by the Bailey Float Type Meter using a Venturi Tube, flow nozzle or orifice as the primary producing device.

This meter is of the open float tube type with differential gearing and cam designed so that the register operates in direct proportion to the rate of flow.

Standard Bailey indicating, recording and integrating instruments are used; charts being 12" in diameter and uniformly graduated. These instruments may be either wall or panel mounted and may be furnished on self-supporting panels if desired.

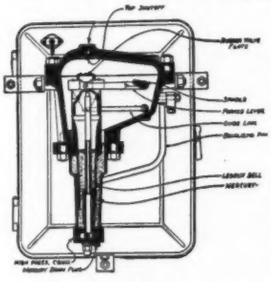
Bailey float type meters are simple, sturdy, neat-appearing and extremely flexible. Capacities may be changed by simple adjustments within the register and remote instruments can be operated from the main register if desired.



Indicating, Recording and Integrating open float tube type Register.

Bailey Flume Meters—Surprising low head losses result from the measurement of water or sewage in open channels when Bailey Flume Meters are used. These simple self-cleaning meters indicate, record and integrate on standard Bailey registers. Instruments may be placed in remote locations by the addition of the Bailey Synchro-Meter transmission system.

Bailey Weir Meter—Highly accurate results in the measurement of sewage or water flowing in open channels are obtained by the use of the Bailey Weir Meter.



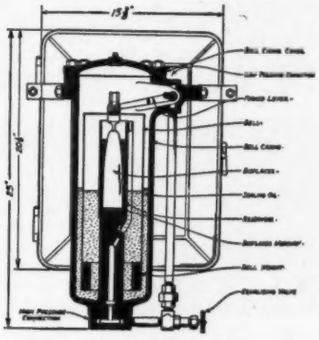
Section through flow mechanism of Ledoux Bell type Register.

Complete flexibility in the location of the standard Bailey registers of this meter may be provided by the Bailey Synchro-Meter transmission system.

Bailey Fluid Meter—The flow of steam, liquids and gases in pipe lines at high or low pressures can be accurately measured by the Bailey Fluid Meter. A Venturi Tube, flow nozzle, or orifice is used as the differential producing device and the meter indicates, records and integrates on the standard Bailey register previously described. Remote recorders may be provided by Bailey Synchro-Meter transmission which operates electrically on alternating current.

In addition to the rate of flow, this meter may also record pressure, temperature or liquid level on the same chart.

Described in bulletin No. 301A.



Section through flow mechanism of Air Meter

Air Meters—These meters measure Air Flow in main lines and in individual lines to aeration tanks.

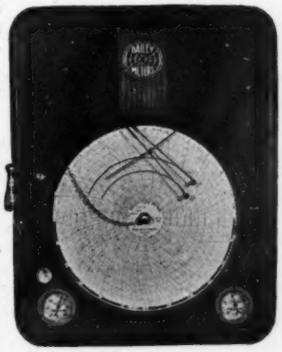
The register is similar in appearance to the Ledoux bell type, and the flow mechanism is designed to operate on a maximum differential pressure of 8-in. of water. *Described in bulletin No.* 301A.

Remote Registers—Bailey Telemetering systems make it possible to operate remote indicating, recording or integrating registers, which may be installed at a distance from the direct connected unit. These registers may measure flow in individual lines, total flow, liquid level, pressure and other factors.

Venturi Tubes—Standard Bailey Designs include a complete range of Venturi tubes and other primary elements suited to the measurement of sewage, sludge and water. The selection of a suitable primary element is governed by such factors as capacity required, type of flanges, pressure loss allowable and character of fluid to be metered.

Controllers—Bailey Controllers utilize standard Bailey Meters and Recorders as the basic measurement source for the automatic control of factors, such as flow, ratio, pressure and liquid level. They are operated by compressed air at approximately 35 lbs. pressure and match perfectly with other Bailey gages and registers.

Bailey control is fully automatic, dependable and exceptionally flexible.



Bailey Recorder—Controller.

Bailey Registers measuring Sewage, Sludge and Air in an operating gallery at Easterly Sewage Treatment Works, Cleveland, Ohio.

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PRODUCTS

BUILDERS WATER AND SEWAGE PLANT *Instruments*

Venturi Meters for Water, Sewage, Sludge, and Air; Flo-Watch Meters for relatively less important lines; Venturi Rate of Flow Controllers; Loss of Head and Rate of Flow Gauges; Reservoir and Tank Elevation Gauges; Sewage, Sludge, and Air Flow and Ratio Gauges. Chronoflo Meters for Distant Metering. Summation of Meter Totals, Continuous Sludge Weighing Chemical Feeding, Suction Well Level and Pump Control. % Proportioneers % Chemical Feeders for Water and Sewage Treating.

ENGINEERING SERVICE

Inquiries for recommendations covering the adaptation of standard metering and controlling devices are invited. Printed bulletins, illustrating and describing devices mentioned briefly in these pages, are available upon request.

VENTURI TUBES—for Water and Sewage

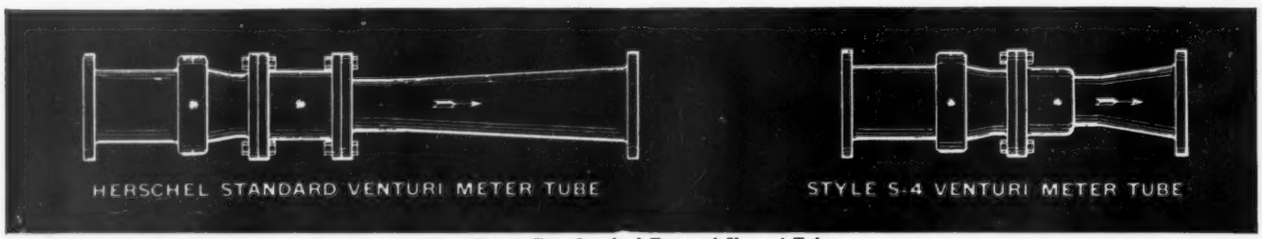


Fig. 1. Two Standard Types of Venturi Tubes

The Venturi Meter is recognized as the standard means of measuring the flow of water in large mains. It consists of the Venturi Tube (Fig. 1), installed as a section of the main, and the Register-Indicator-Recorder (or other Instrument) connected to the Tube by two small pressure pipes. The proportions and length of the Herschel Standard Venturi Tubes were selected by the inventor from extensive experimentation and are designed for a minimum pressure loss. This usually has a definite economic value since it lowers pumping costs. Throat sections for these Tubes are completely interchangeable. The Style S-4 Venturi Tubes are shorter, somewhat lower in price, but throats are not as interchangeable and pressure loss is somewhat greater.

For the measurement of liquids containing solids, such as sewage or sludge, the **Air Relay Transmitter** is used to prevent the liquid from coming into contact with the instrument.

KENNISON NOZZLES —for Open Flows

This nozzle accurately measures flow through partially filled pipes and open channels where there is a wide variety in flow rates. They are available in sizes from 6" to 36" and are used with the Instruments shown below.

Fig. 2. Kennison Nozzle for open flows

BUILDERS INSTRUMENTS—for Use with Venturi Tubes, Kennison Nozzles, Orifice Plates, and Weirs

Fig. 3. Type M Register-Indicator-Recorder, Model D

Builders Instruments have been widely installed for measurement of flow under all kinds of operating conditions and have earned for themselves the hearty recommendation of engineers and operating men. **Type M Register-Indicator-Recorders** (Fig. 3) are the most popular instruments and have the advantage of unusual ruggedness and extreme accuracy. The Type M furnishes three distinct kinds of information; an indication of the momentary flow through the Venturi Tube; a permanent record of this rate upon a large circular chart; the total quantity on a circular counter dial. Each type M is graduated for the particular Venturi Tube with which it is to be used.

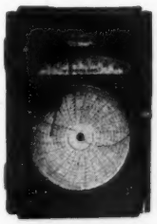


Fig. 4. Flo-Watch Register-Indicator-Recorder

The Flo-Watch, Fig. 4, is an accurate, mechanical instrument designed for use on main lines in small plants and secondary lines in large plants. It records, indicates, and totalizes the flow.

Simplest of all, is the **Barometric Type Mercury Manometer,** which has a flow rate scale graduated directly in flow units, and indicates the rate of flow.

VENTURI FILTER RATE OF FLOW CONTROLLERS

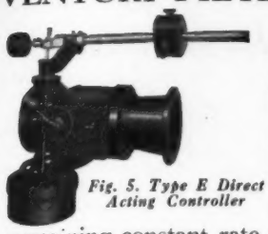


Fig. 5. Type E Direct Acting Controller

Venturi Controllers have been standard equipment in filtration plants for many years. At present several types of controllers are offered, each type designed to serve particular conditions in automatically maintaining constant rate of flow through the filter bed.

The Type E Direct Acting Controller (Fig. 5) features include: precise control, low loss of head, rigid balanced valve, compact, yet flexible design, powerful "floating piston" actuation, and exclusive molded, tapered piston seal.

The Types A and B Controllers are hydraulically operated. Type A has a controller valve of the gate type with specially designed seat; Type B has a double butterfly valve and is for the larger effluent lines.

Wash Water Controllers, Manual Master Controllers, and Clear Well Master Controllers are also available—information upon request.

BUILDERS GAUGES—for Water & Sewage Plants

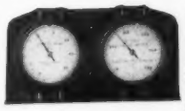


Fig. 6. Rate of Flow and Loss of Head Gauge

Builders Gauges are the result of nearly a half century's experience in designing, manufacturing, and furnishing such instruments for hundreds of plants. Mechanically they have been reduced to simple elements; externally they are styled and finished to harmonize with the attractiveness of modern filtration plant interiors.

Rate of Flow and Loss of Head

Rate of flow and loss of head gauges, Fig. 6, are mounted usually on the operating table, convenient to valve controls, but can be mounted on self-supporting floor stands where desirable. The indicator and chart display the information gathered by the differential-responsive units; upon these the gauge depends for accurate, powerful actuation. Builders Diaphragm Pendulum Units, after more than a decade of service in plants operating under all sorts of conditions, have earned the emphatic approval of water works engineers.

Water Level Gauges

Used for indicating and/or recording water level in basins, tanks, and reservoirs. Such gauges are operated by a spherical copper float in a pipe or well. Indicator dials and charts are graduated to read directly in feet of depth, elevation, or other specified units.

Chronoflo Long Distance Gauges (Fig. 11), are extremely convenient for indicating and recording level in outlying reservoirs and stand-pipes.

Large Dial Gauges

Fig. 7. Large Dial Gauge

Builders Large Dial Illuminated Gauges, Fig. 7, available in 24" and 30" sizes with single or double faces for wall or ceiling mounting, are commonly used in water works to make readings visible to the operator from any point in the operating gallery or pump room. Important features include the concealed double hinges, which allow access to mechanism without removal from wall, and indirect gas tube illumination which gives uniform soft glow around entire circumference of dial.

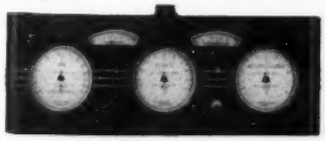


Fig. 8. Five Dial Ratio Gauge

Ratio Indicating Gauges

In sewage plant service efficiency of operation is maintained by a knowledge of the ratio between air/sewage, air/sludge, etc. Special gauges, Fig. 8, are available for this service.

CHRONOFLO METERS AND THEIR APPLICATIONS

Since their introduction a decade ago, Chronoflo Meters have found broad applications in water and sewage plant service in bringing to a central operating point, from widely scattered locations, accurate records of flow, Fig. 10, level, Fig. 11, pressure, temperature, gate position, and weight, Fig. 13. Chronoflo Transmitters are electrically connected by a simple two-wire circuit to Chronoflo Receiving Instruments.

Fig. 9. Chronoflo Recorder

Distant Metering

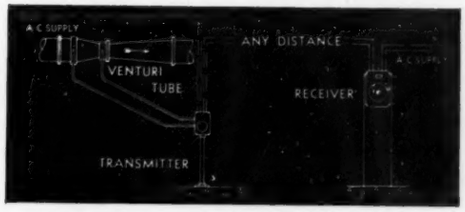


Fig. 10. Flow through a Venturi Tube transmitted to Chronoflo Recorder at distant point

Tank Level and Pump Control

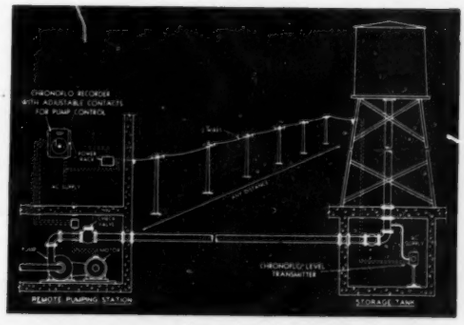


Fig. 11. Level in distant elevated tank is recorded; and pump is controlled by Chronoflo

Control of Chemical Feeders

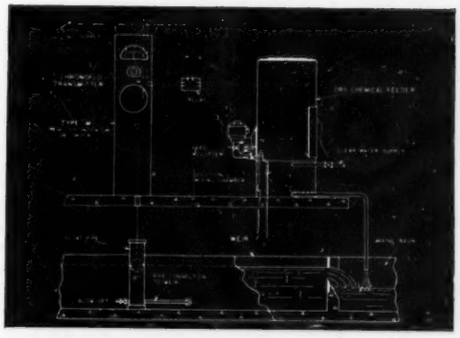


Fig. 12. Flow over a weir controls rate of chemical feeding, using a Chronoflo Transmitter

Automatic Sludge Weighing

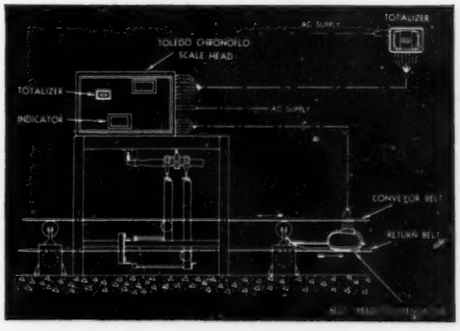


Fig. 13. Toledo-Chronoflo Continuous Conveyor Scales are used for automatic sludge weighing

MAIN-LINE METERING OF WATER, SEWAGE AND SLUDGE

By ROBERT T. REGESTER
Consulting Engineer, Baltimore, Md.

AN accurate and convenient means for metering the flow of water in main pipe lines presented an unsolved problem in early American hydraulic and water supply practice. It was not until 1887 that Clemens Herschel, eminent New England engineer, conceived the idea of applying the Venturi principle as a practical method of flow measurement. After conducting elaborate experiments, he invented and successfully calibrated a compound conical tube which he named the "Venturi meter." In 1891 the meter was first installed by the East Jersey Water Company. Its success was immediate and marked a notable contribution to hydraulic engineering. Twelve years later, the first Venturi meter for the measurement of sewage was installed in a large discharge pipe at the Ward Street Pumping Station of the Boston sewerage system. This installation was also successful and continues in operation today.

Since these first applications, continuous developments and improvements have been made in Venturi metering, particularly with regard to automatic registering and recording instruments. Today Venturi meters and their related devices are used throughout the world in both water works and sewerage systems for a variety of purposes. They are recognized as invaluable aids to the efficient operation and control of modern water purification plants and sewage treatment works. Although other metering elements are available, the Venturi meter is the universal standard for the measurement of water, sewage and sludge flowing through main pipe lines.

Venturi Tubes

A standard Venturi tube, as shown in Figure 1, comprises a cylindrical inlet, a converging inlet cone, an intermediate "throat" section and a diverging outlet cone. The inlet cone has a rather

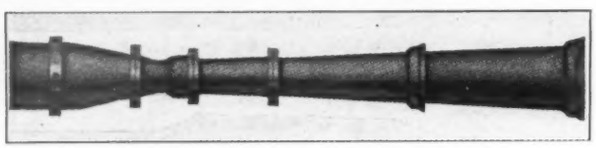


Fig. 1—The Herschel Standard Venturi Tube

steep taper while the outlet cone tapers more gradually. The interior passageway of the tube is entirely unobstructed. The sections of these tubes are usually made of cast iron with throat part bronze-lined to resist corrosion. The inlet and outlet cones are occasionally constructed of either reinforced concrete or steel plates. At both the inlet and the throat of each tube, an annular pressure chamber communicates with the interior by means of numerous small and equally-spaced vent holes. These annual chambers are basically important features of Venturi tubes. The essential purpose of each chamber is to average the pressure head at several points around the tube's circumference, thus avoiding the inaccuracies otherwise introduced by using a single-vent piezometer.

The favorable hydraulic properties of the standard Venturi tube are unequalled by any other type of metering device for main pipe lines. If piezometers are inserted along a standard Venturi tube, the hydraulic grade line will follow the curve as illustrated in Fig. 2. The velocity of flow rapidly accelerates from the inlet to the throat, and thereafter gradually decelerates through the outlet cone. Accordingly the pressure head which is greatest at the inlet end rapidly decreases to the throat where it is least. This difference in pressure bears a definite relation to the velocity of flow and therefore, the quantitative rate of flow. This function varies approximately as the square of the velocity in the throat. It should be particularly noted that the pressure is gradually regained as the velocity decreases in the outlet cone, until at the outlet end nearly all of the original pressure head has been restored. The overall pressure drop, or "friction loss," between the inlet and outlet ends is relatively small for normal rates of discharge, and for low rates it is negligible.

The size of a Venturi tube is expressed by the diameter of the inlet and outlet ends, in inches, which usually is the same nominal diameter as the pipe line for which the tube is intended. The standard tube of Herschel proportions has an average length of about nine inlet diameters, but the exact length depends upon the throat diameter. For installations where the conditions are favorable, shorter and somewhat less costly Venturi tubes are available. In general, these are similar in construction to the standard tubes, but have outlet cones of sharper taper with consequent greater friction loss. Certain special designs of tubes are also made, such as elliptical, constant-acceleration and flat-invert (or eccentric type). In instances where low points cannot be readily drained, or where overhead clearances are very limited, the flat-invert tube may be desirable. However, such tubes are considerably more costly than standard concentric tubes, which experience has demonstrated to be most suitable for normal installations.

For the measurement of sewage and sludge, Venturi tubes require certain special appurtenances. At the inlet and throat pressure chambers, vent-cleaning valves are necessary so that, at intervals, the vents can be cleaned of deposits and the pressure chambers flushed. An individual hand valve is often provided for each vent. However, a recent device (Fig. 3) is available for simultaneously actuating all of the vent-cleaning valves by the operation of a single water- or air-pressure supply valve. Hand holes near the inlet and the throat are useful for an occasional inspection of the interior surface of a tube. In cases where the sewage contains corrosive industrial wastes, a special split-flange section of tube can be provided to expose the entire throat part for examination and cleaning.

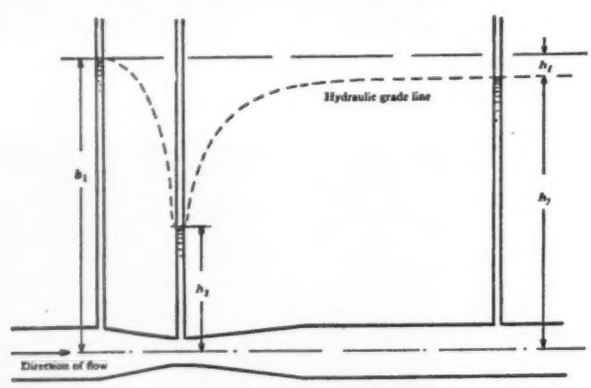


Fig. 2—Hydraulic Grade Line for Flow Through a Venturi Tube

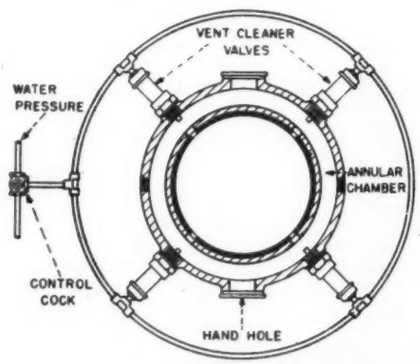


Fig. 3—Hydraulic Vent Cleaning Assembly for Simultaneous Operation

Other Types of Meters

Orifices and Nozzles

Among other types of meters available for main pipe lines are orifices and flow nozzles. Orifices can be obtained in several forms, the most familiar of which is a circular opening in a flat plate clamped between a pair of flanges in the pipe line. The hole of the orifice may be either concentric or eccentric in the flat-plate type. Piezometer connections are made on each side of the orifice plate by tapping two small tubes into the main pipe line. The differential pressure between the inlet and outlet sides of the plate is used to actuate the metering instrument. Orifice plate assemblies with annual pressure chambers, tapped for piezometer connections, are available.

The hydraulic grade line for a plate orifice is shown in Fig. 4. With flow through the main pipe, the pressure head drops abruptly at the orifice and continues to decrease slightly opposite the plane of greatest contraction just downstream from the plate. Beyond this plane the pressure then increases with partial recovery of the original pressure head. Because of the plate projection inside the pipe considerable turbulence results; hence the overall

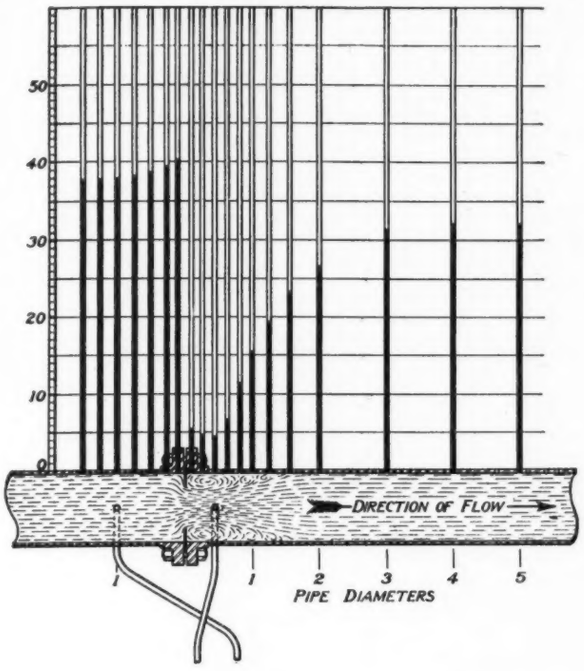


Fig. 4—Hydraulic Grade Line for Flow Through a Concrete Plate Orifice

friction loss for a given ratio of orifice and pipe diameters is much greater than for a Venturi tube having the same ratio of throat and inlet diameters.

If used for the measurement of sewage and sludge, plain orifice meters may be subject to inaccuracies resulting from erosion of the edge and accumulation of solid matter at the projection. Certain specially shaped orifices, or so-called "flow nozzles," resembling Venturi tubes can be furnished to overcome some of the disadvantages of the plate orifice.

The Kennison Nozzle

The Kennison open-flow nozzle is suitable for measuring flows of sewage, industrial wastes and sludge in partially filled pipes and open channels. This nozzle is bolted to the outlet end of a main pipe line with free discharge. The design utilizes the inlet depth produced by a specially shaped outlet for the rate-of-flow function which varies directly with the head. At the inlet of the nozzle, a connection is made to a float tube for operating the metering instrument, Fig. 5. Kennison nozzles are made in inlet sizes varying from 6 in. to 36 in. diameter. Another type of nozzle for partly filled pipes utilizes the discharge-angle relation, produced by a vane which receives the discharge impact, as the rate-of-flow function. This latter nozzle (Schofield) has a parabolic outlet.

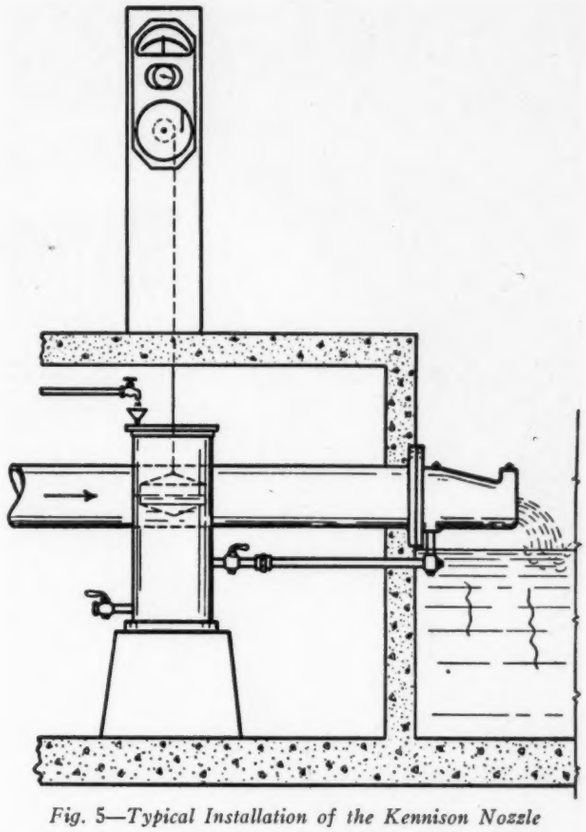


Fig. 5—Typical Installation of the Kennison Nozzle

The Parshall Flume

For the measurement of sewage flows in open channels, the Parshall flume is now extensively used. This Venturi shaped flume usually operates as a free-flow device and therefore requires the use of a single pressure head to accurately determine the discharge rate. The flume was originally developed and is widely used in the West for irrigation purposes. The first important installation for measuring sewage was at Providence, R. I., in 1931, where a large flume having a capacity of 120 M.g.d. with throat width of 10 ft. (Fig. 6) meters the effluent from the sewage treatment plant. An important characteristic of the Parshall flume is the relatively small loss of head, which is about one-fourth that of the standard weir for free flows. This flume is adaptable for both large and small plants and has been calibrated for a variety of sizes and corresponding capacities. A pipe connection is made on the tapering inlet side of the flume for the float actuation of a metering instrument.

Discharge Coefficients and Friction Losses

With any type of meter for main pipe lines, the accuracy of measurements must be supported by exact knowledge of the discharge coefficient and its relation to the size, ratio and other characteristics of the respective type. The accuracy of the Venturi meter has been established through numerous carefully conducted calibration tests by hydraulic laboratories and prominent manufacturers. Such tests have demonstrated that the high initial accuracy of the Venturi meter remains unimpaired during years of continuous service. Coefficient curves for standard Venturi tubes (as made by Builders Iron Foundry and the Simplex Valve & Meter Co.) are available in the A. S. M. E. —Fluid Meters Research Publication, Part I, 1937. In addition thereto, various types of upstream disturbances have been analyzed with regard to Venturi tubes and corrective vanes have been studied by Prof. W. S. Pardoe (Trans. A. S. M. E.—Nov., 1936, and Nov., 1937). Also, a valuable study of the proper application of piezometer connections to metering devices was made by Messrs. Allen and Hooper (Trans. A. S. M. E.—1931) as a further contribution toward meter accuracy.

The overall friction loss produced by a differential metering device in main pipe lines is frequently of economic importance. Such losses may substantially increase annual pumping costs, or may materially decrease the gravity head which is available for

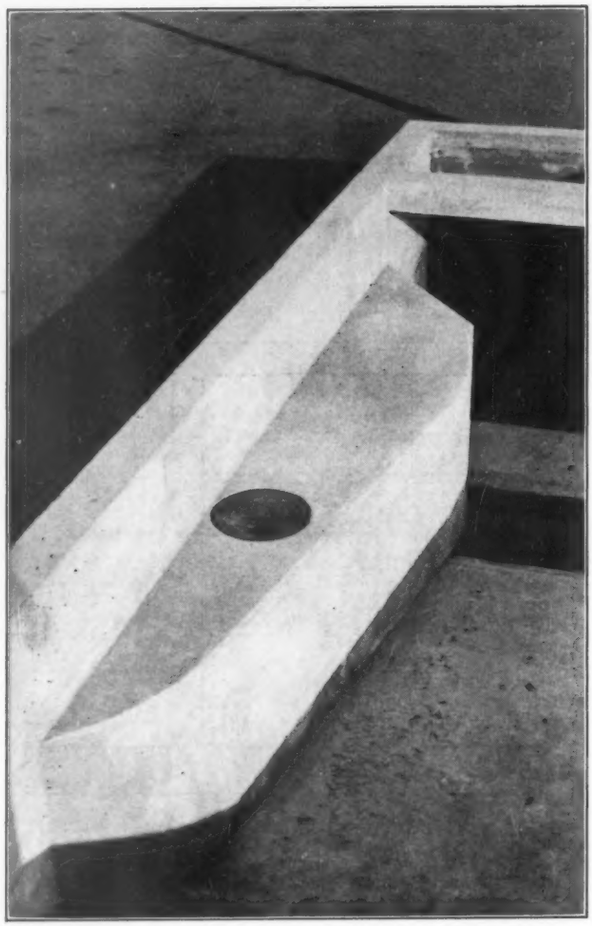


Fig. 6—One-Half of the Parshall Flume, Looking Downstream to Throat Section—Providence, R. I.

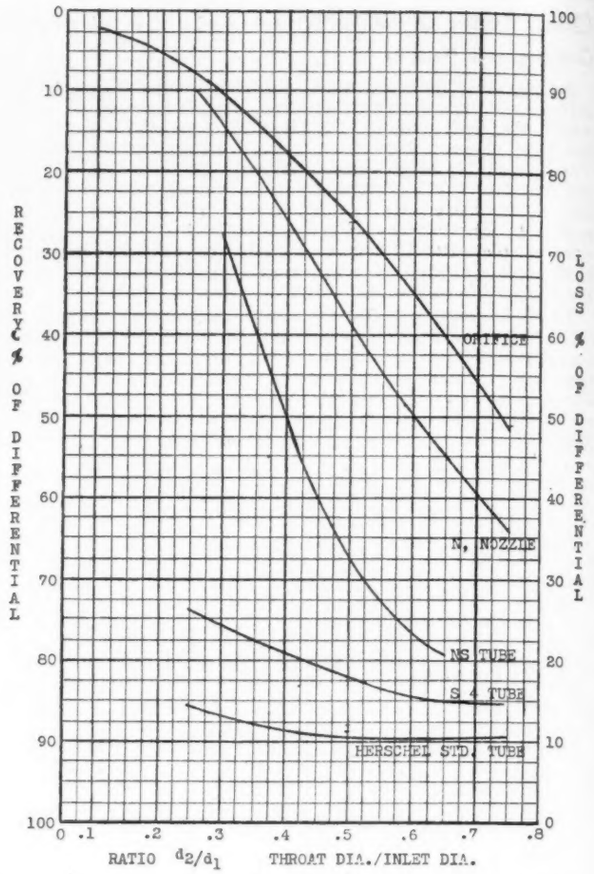


Fig 7—Recovery Characteristics and Friction Losses of Various Differential Producers

For Figs. 8 and 9, see next page.

other essential purposes in both water purification and sewage treatment plants. This latter condition may involve greater construction costs due to the lowering of structures to meet the resulting hydraulic grade lines. In either case, a small initial saving in the price of an unsuitable meter may be insignificant in comparsison with the ultimate cost incurred by excessive fraction loss. Accordingly, that metering device in which the recovery of inlet pressure head is the greatest will most likely prove to be the most economical selection.

The accompanying diagram, Fig. 7, strikingly presents a comparison of the recovery characteristics and friction losses for a standard Venturi tube of Herschel proportions, a short Venturi (S4) tube, two types of flow nozzles (NS and N) and an orifice plate. These data are expressed thereon as precentages of the differential head for various ratios of throat and inlet diameters. For the frequently used ratio—0.5, it should be noted particularly that the corresponding friction loss for an orifice is about seven times the loss for a Herschel standard tube.

Herschel standard Venturi tubes have a fraction loss of only 10% to 15% of the differential head for a ratio of 0.25 to 0.75—throat to inlet diameter. In comparison, the fraction loss for orifices is much greater and varies from 49% to 92% of the differential for the same ratio range of orifice opening to pipe diameter.

Venturi Metering Instruments

A variety of instruments for the measurement of water and sewage in connection with Venturi tubes and other differential metering devices is available. Each type is actuated by the differential head, either by direct connection or by some medium of transmission such as air or electricity. Several types of instruments are illustrated in Fig. 8 and 9. The mechanism of one prominent type is shown in Fig. 10. At the rear of the register two large mercury wells, connected at the bottom to form a U-tube, receive the differential pressure from the Venturi

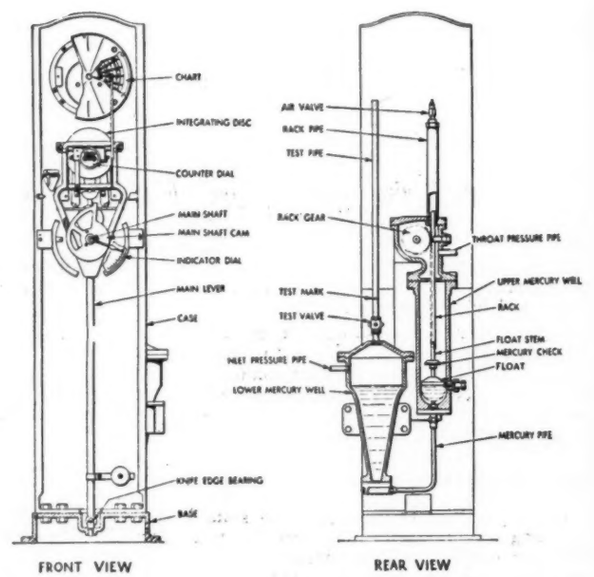


Fig. 10—One Example of the Pressure Chamber Type of Register Mechanism, with Rack and Gear Transmission of the Float Movement

tube through small pipes from the inlet and the throat. One of the mercury columns supports a solid metal float of large diameter, which is responsive to minute variations in mercury levels. Through a positive rack and gear transmission, the float

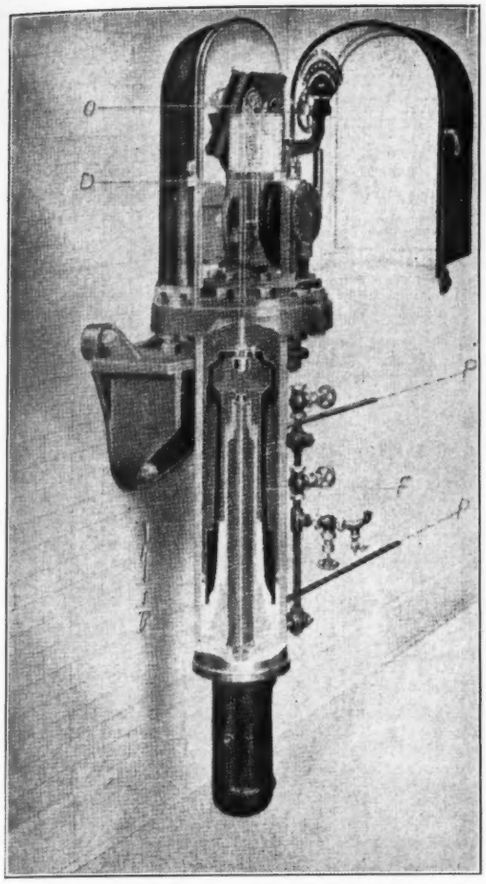


Fig. 8—Pressure Chamber Type of Instrument Using Mercury Sealed Bell (Courtesy of Simplex Valve & Meter Co.)

For Fig. 10, see preceding page.

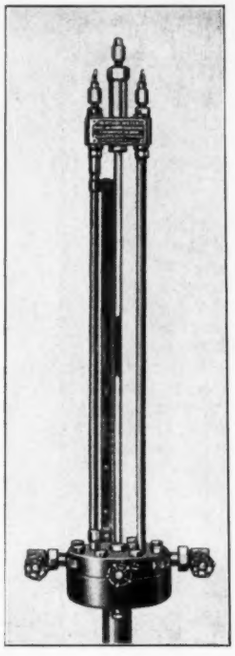


Fig. 11—Portable Flow-Rate Indicating Instrument of the Barometric Type

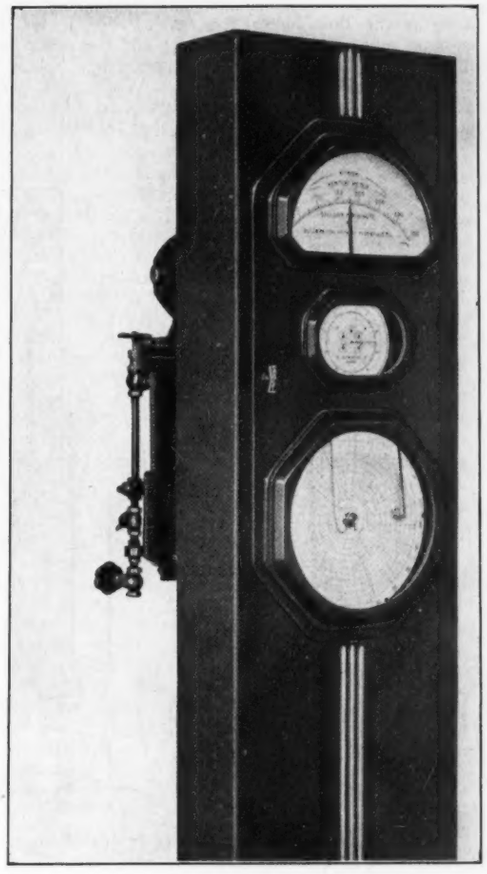


Fig. 9—Modern Register-Indicator-Recorder, with Pair of U-Tube Mercury Wells (Courtesy of Builders Iron Foundry)

movement establishes the position of the rate-of-flow indicating hand, the rate recording chart pen and the driving roller of the motor-driven totalizer. These are respectively the upper, lower and middle dials (Fig. 9).

A simple mechanical instrument, suitable for main pipes in small plants and for less important pipes in large plants, is very similar to the instrument shown in Fig. 13. This instrument can be used with either Venturi tubes or orifices for the measurement of water, sewage, sludge, air and other fluids. Principal features of this device are compact design, gear-driven integrator and universal mounting for floor, wall or panel.

A portable and sturdy flow-rate indicating instrument of the barometric type is shown in Fig. 11. The rate scale, 22 in. long, can be graduated to read directly in units of flow. The slightest change in rate through the Venturi tube, or other differential producer, will cause an immediate and relatively large response in the vertical movement of the mercury column within the single glass tube. In addition to this instrument, several types of manometers can be obtained for a variety of purposes. A double-tube type is especially suitable for general testing work. Graduations can be either in inches of deflection, or directly in rates of flow.

Where the conditions of installation make the use of mechanically actuated instruments impracticable, electrically-operated transmitters with receiving instruments can be employed for remote metering indications and recordings. Numerous types or systems have been developed such as time impulse, stepped resistance, self-synchronous motor pairs and others.

The time impulse system is used with Chronoflo transmitter and receiver instruments, Fig. 12 and 13. The transmitter receives the differential pressure, and is usually installed close to the Venturi tube or other differential device. It contains a mercury float, a synchronous motor-driven mechanism and a magnetic mercury switch. These elements are so interconnected that for a portion of each cycle (¼ to 1 minute), varying in duration in exact proportion to the rate of flow, electrical "time impulses" are sent to the distant receiving instrument. The latter, through motor-driven magnetic clutch elements, translates these impulses into flow units on the dial and chart.

Weather-proof instruments for installation out of doors are readily available with substantial weather-proof metal housings.

Metering instruments are logical sources of signal and control actions as related to flow rates. Lights, sound apparatus, power relay switches and other electrical elements can be readily actuated by such instruments at relatively small cost.

Methods of Installation

Two simple methods of installing Venturi tubes and instruments for the measurement of water are shown—Fig. 14. That for medium and high heads is on the left, and the method for low heads on the right. When the pressure is ten pounds or

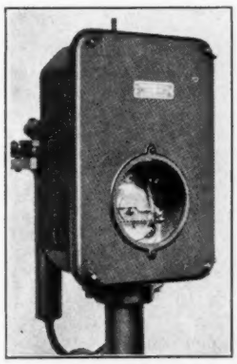


Fig. 12—Transmitting Unit

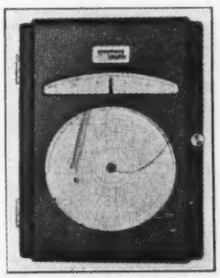


Fig. 13—Receiving Unit

Chronoflo Time-Impulse Instruments for Remote Metering (Courtesy of Builders Iron Foundry)

more at the floor where the instrument is located, two small pressure pipes—one from the inlet and the other from the throat of the tube—form a direct connection. These pipes can be several hundred feet in length. Where the acting hydraulic head is low (e.g. raw water supply to filter beds) the usual mercury wells at the back of the registering instrument are

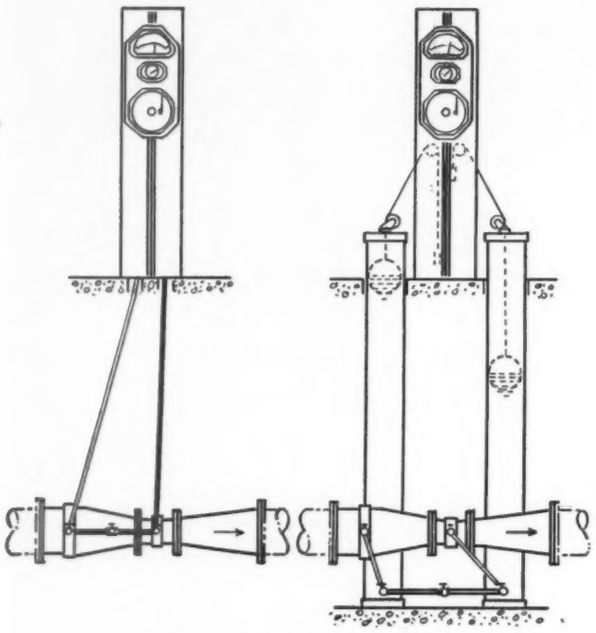


Fig. 14—Venturi Meter Installations
Left—For Medium and High Heads
Right—With Float Tubes for Low Heads

removed and vertical inlet and throat float tubes are substituted. Cables from these floats lead to a differential actuating mechanism at the back of the instrument.

Other types of installation require the mercury wells to be placed at a low elevation with a cable connection to the register above. With any of these types for the measurement of sewage and sludge, provision must be made for seals to prevent deposits from reaching the registering instrument through pressure connections, or for proper flushing with clean water. Such flushing may be either continuous or manually regulated, as the requirements dictate.

Air Relay System

The use of compressed air as a medium for the transmission of the inlet and throat pressures of a Venturi tube, or other differential producer, to a distant recording instrument is frequently advantageous. One type of "air relay system" employs two diaphragm units, one directly connected to the inlet and the other to the throat of the Venturi tube. Each unit consists (Fig. 15) of a hollow chamber (C) which is divided into two compartments by a solid rubber and fabric diaphragm (D). The inner side of the diaphragm is subjected to the liquid pressure from the tube; the outer side receives an external air pressure to balance the liquid pressure on the inner side. Air is continually vented through a throttled needle valve (N) attached to the diaphragm unit. Two small pipes, one from the inlet and the other from the throat relay unit, are connected from the outer compartments to the usual mercury wells at the rear of the registering instrument. The transmitted air pressures are exactly equal, respectively, to the actual inlet and throat pressure heads in the Venturi tube.

This type of unit forms a seal between the tube and the instrument, which is especially important in metering sewage and sludge. In the measurement of sludge, unless it is "thin," it is necessary to provide continuous water flushing through appropriate small sight-feed orifices.

Another well known type of air relay system operates with a single air pressure which is proportional to the amount of the liquid differential pressure.

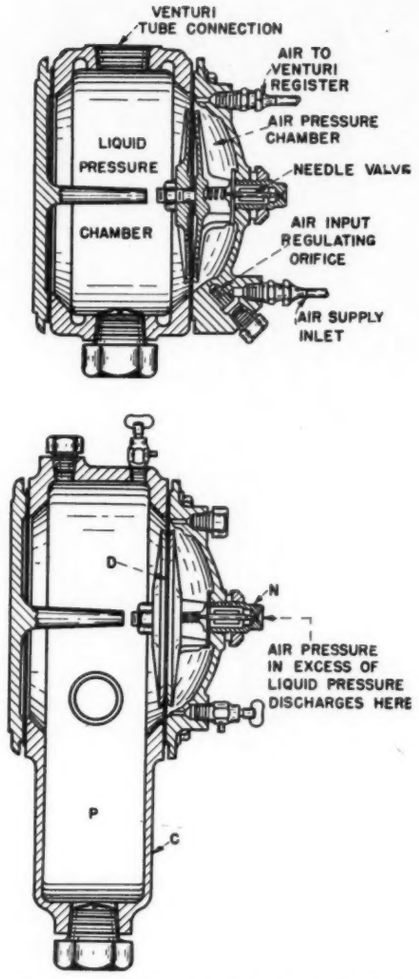


Fig. 15—Diaphragm Unit for Air-Relay System

Flow Summation

Recent developments make it possible to summarize, on a individual meters in their respective discharge pipes. It may be single instrument, the readings of several meters. For example, a water works pumping station may have several pumps with desirable to totalize these separate flow rates for purposes of accurately introducing chemicals, such as chlorine, without wastage. In this case, an electrical transmitter (such as Chronoflo) can be attached to each registering instrument (Fig. 16). The impulses sent out by these transmitters go to a master unit which integrates the respective values, and then transmits the total to distant summation indicating, recording and totalizing instruments, as required.

In sewerage districts and sewage treatment plants, the summation principle can be utilized to great advantage. Sewage flows from scattered communities can be summarized and transmitted to the central or joint treatment plant for the guidance of the operator, and for the allocation of operating charges. Likewise, flow divisions within a large sewage plant can be summarized for control purposes.

Means can also be provided to give the difference in readings for two meters, or the difference of the combined rates of flow in groups of meters.

Special Metering Instruments

The marked trend in recent years of centralized control in water purification and sewage treatment has been accompanied by a fulfilled demand for the broader performance of main pipeline meters. Distant transmission by air or electricity to centralized panels and control tables, the ratio of one flow to another, the summation of flows to one or more central dials, the automatic

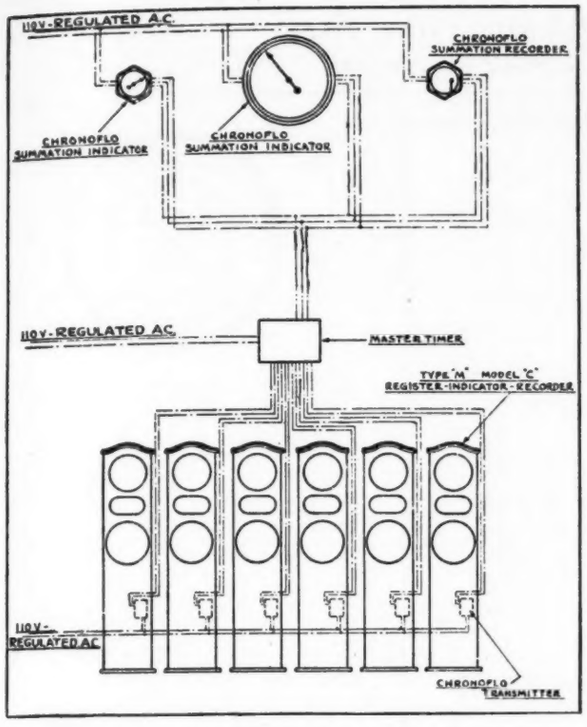


Fig. 16—Diagrammatic Arrangement of Flow Summation Instruments for Cermak Station, Chicago

controls of flows and distant pumps to maintain perdetermined levels or rates, the proportioning of chemical dosages to main flows and other functions, are examples of modern metering requirements. The design and finish of the instruments themselves have been "modernized" to harmonize with the present architectural attractiveness of plant interiors. Effective illumination has been likewise provided for single- and double-faced master indicating gauges, frequently of large diameter.

A flow and ratio gauge for each unit in a modern activiated sludge plant is illustrated, Fig. 17. There are five dials, the three largest showing (left to right) rates of air flow, sewage flow and return sludge flow to an aeration tank. The two smaller dials show (left) the ratio of air to sewage—in cu. ft. per gal., and (right) the ratio of return sludge to sewage—in per cent of sewage flow. In addition, there is an automatic control knob for pre-setting the latter ratio for any desired value. A pair of these five-dial gauges are mounted on one control table similar to those used in water filter plants.

Installation Requirements

To insure the proper application of metering equipment, specific data should always be obtained from the meter manufacturer for a particular installation. However, in general, certain standard requirements are noteworthy.

The Venturi tube should preferably be preceded by a straight length of pipe having the same diameter as the tube; this length being at least six times the tube diameter up to 24 in. and at least 12 ft. for larger sizes. Where space is limited, or there is the probability of turbulent or spiral flow ahead of the tube, straightening vanes may be required. Any kind of fitting may be placed at the outlet end of the tube. Since the centrifugal pump is almost universally used in water works and sewerage systems, pulsations in flow are rarely encountered. However, such condition may occasionally be presented and must receive special consideration. It is essential in making pressure pipe connections that they be run on a continuous grade, avoiding summits or depressions where air or silt may collect.

The Parshall flume must be set at the proper elevation with respect to the channel, preferably so that it can operate at all times under "free flow" conditions, with a limit of 95% submergence. It should be located in a reasonably straight section of channel, where the distribution of flow is fairly uniform. The flume, however, will operate satisfactorily under rather poor approach conditions. The dimensions and proportions of the flume must adhere to the established standards.

In installing the Kennison nozzle, care must be taken to provide proper approach conditions. This device should be preceded by a section of pipe at least eight diameters in length, and the water or sewage must flow smoothly from the nozzle under free discharge. Any conditions of installation which might cause a "shooting velocity" at times, should be corrected by the use of proper fittings upstream.

Orifice plates are more sensitive to approach conditions than Venturi tubes, and require a straight length of smooth pipe both upstream and downstream from the plate. For the upstream, the length required may vary from five to thirty diameters, while for the downstream length—up to eight diameters, depending upon the piping layout and the diameter ratio. Straightening vanes may be required to eliminate swirls, cross currents and eddies; their use may make it possible to shorten the necessary lengths of pipe as just mentioned.

Conclusion

Certain fundamentals of main line metering and some of the modern developments in metering equipment have been briefly discussed. Emphasis is placed upon the importance of regarding each meter installation as an engineering problem, which requires the consideration and advice of experienced manufacturers. Low cost equipment may properly serve for relatively unimportant work, but is entirely unsuitable for checking the daily performance of main units and for controlling the efficiency of treatment processes. In general, the highest grade of equipment as offered by prominent manufacturers cost only a small fraction of the total construction contract on important projects. Obviously, the best is the wisest selection.

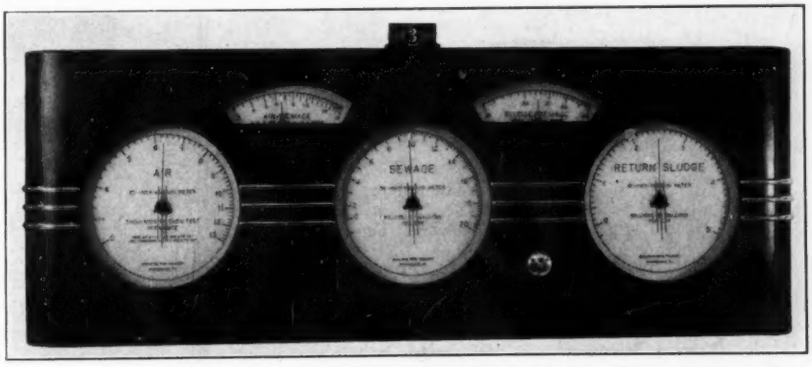


Fig. 17—Special Flow and Ratio Gauge for Modern Activated Sludge Plant, Baltimore, Md.

SIMPLEX VALVE & METER COMPANY

6743 UPLAND ST., PHILADELPHIA, PA.

Water Works and Sewage Plant Equipment

SIMPLEX Water Works and Sewage Plant equipment is designed and constructed to comply with the specific requirements of each installation. Simplex control and metering equipment has earned an enviable reputation because of its simplicity of design, accuracy, dependability and low cost of maintenance.

Your selection of Simplex equipment will assure you of obtaining control and metering devices of dependable and proven design, capable of providing the type of service necessary for maintaining proper and economical functioning of your plant.

SIMPLEX EQUIPMENT FOR WATER AND SEWAGE TREATMENT PLANTS:

- Air Release Valves
- Air and Vacuum Valves
- Flow Controllers for—
  - Effluent
  - Raw Water
  - Wash Water
  - Chemicals
  - Sewage
  - Sludge
- Indicating and Recording Gauges for—Rate of Flow
  - Loss of Head
  - Sand Expansion
- Air-Differential Meters for
  - Water
  - Sewage
  - Sludge
  - Corrosive Liquors
- Water Waste Survey Equipment
- Proportional Control and Solution Feed Devices
- Venturi Type Meters for All Services
- Orifice Type Flow Meters
- Pump Casing Tap Meters
- Flow Recorders
- Flow Indicators
- Flow Totalizers
- Indicating, Recording and Totalizing Meters for
  - Steam
  - Air
  - Gas
  - Water
  - Sewage
  - Sludge
- Pitot Rods and Manometers
- Simplex Egg-Shaped and Impact Flume Meters
- Simplex Parshall Flume and Weir Meters of the Indicating, Recording, and Totalizing Types.

REPRESENTATIVES IN THE FOLLOWING CITIES

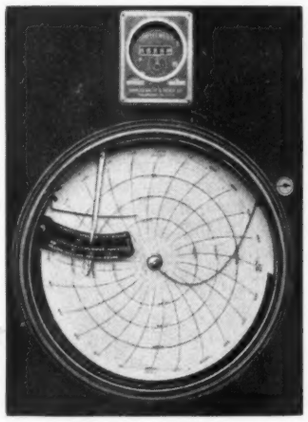
Atlanta, Georgia	Detroit, Michigan	Omaha, Nebraska
Baltimore, Maryland	El Paso, Texas	Pittsburgh, Penna.
Boston, Mass.	Kansas City, Mo.	Rochester, N. Y.
Charlotte, N. Carolina	Los Angeles, Calif.	San Francisco, Calif.
Chicago, Illinois	Louisville, Kentucky	Salt Lake City, Utah
Cleveland, Ohio	Milwaukee, Wisconsin	Seattle, Washington
Dallas, Texas	New Orleans, La.	Tulsa, Okla.
Denver, Colorado	New York City, N. Y.	

FOREIGN

Bogota, Colombia	Havana, Cuba	Malay States, Singapore
Buenos Aires, Argentina	Honolulu, Hawaii	San Juan, Puerto Rico
Caracas, Venezuela	Madero, Mexico	Toronto, Ontario, Can.

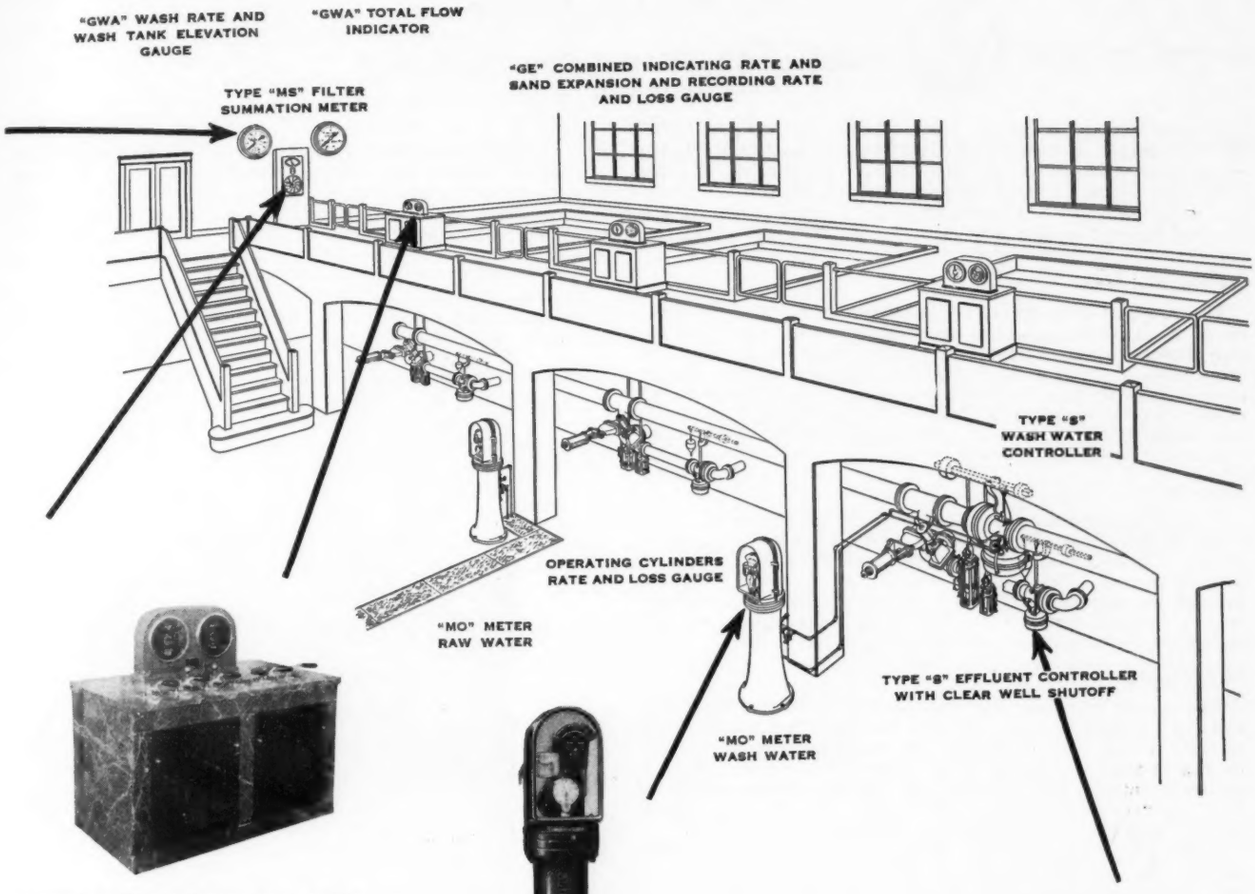
SIMPLEX DISPLAY GAUGES

The Simplex "GWA" display gauge can be furnished from 12" to 36" in diameter and can be actuated directly from the primary device or by electrical means from a meter gauge or control unit. Used when remote indications of level, rates of flow, or other indications must be visible at long distances, the "GWA" gauge is specifically designed to harmonize in appearance with the gallery architecture.



SIMPLEX VENTURI TYPE METERS

The Simplex Type "MS" meter is of the mercury float, mechanically operated type. The direct application of differential pressures upon the float unit moves this in direct proportion to the flow rate providing uniform graduations and direct reading of indicator, chart, and totalizer. Available as an indicator, recorder and totalizer or as any combination of these functions, the MS meter can be furnished for wall or panel mounting, high or low head service, and with either segmental indicator or separate indicator as shown. Simplex "MS" meters are capable of measuring all flows over ranges of from 6½ to 1 to 20 to 1, within an error of ±2%. They can also be furnished for water float operation in conjunction with weirs and flumes.


"GWA" WASH RATE AND WASH TANK ELEVATION GAUGE
"GWA" TOTAL FLOW INDICATOR
"GE" COMBINED INDICATING RATE AND SAND EXPANSION AND RECORDING RATE AND LOSS GAUGE
TYPE "MS" FILTER SUMMATION METER
TYPE "S" WASH WATER CONTROLLER
OPERATING CYLINDERS RATE AND LOSS GAUGE
"MO" METER RAW WATER
TYPE "S" EFFLUENT CONTROLLER WITH CLEAR WELL SHUTOFF
"MO" METER WASH WATER

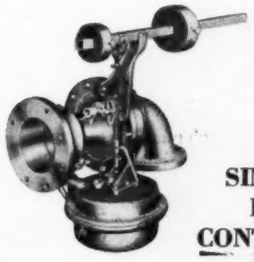
SIMPLEX FILTER GAUGES

Simplex Filter Gauges can be furnished singly or in any combination to indicate and/or record filter loss of head, rate of flow and sand expansion. The actuating element for the rate of flow and loss of head gauge consists of the self contained shaped mercury float unit, whose movement, due to the application of differential pressures, is transmitted to the indicating or recording units by means of non-corrodible monel metal linkages. The gauge heads can be designed for either floor stand or table mountings as desired and indicate and record on uniformly graduated direct reading dials and charts. The Simplex Sand Expansion Indicator provides a definite means of establishing and maintaining optimum efficiencies during the washing period. Simple in design and ruggedly constructed, its use, in over fifty plants, has resulted in the reduction of wash water consumed and in the elimination of sand cracks and mud balls. Increases in filter runs by as much as fifty percent have been obtained after its use as a means of obtaining maximum washing efficiency.

THE SIMPLEX "MO" METER

The Simplex "MO" Meter is perhaps the most widely used Venturi Type Meter now made. Actuated by the well-known Simplex Bell Shaped Float, this instrument provides a means of obtaining ac curate measurement of fluid flows over remarkably wide ranges. Operating on a relatively small differential head, the "MO" Meter, with its Venturi, produces at maximum flow an unrecoverable head loss of less than 1.5′ of water.

Available in the indicating, recording and totalizing form, Simplex Meters can be operated by means of either direct application of the Venturi head or by the Simplex Air Differential Principle. It can also be arranged for remote transmission of flow readings by the use of self-synchronous motors if desired. Responsive to differential heads of as little as ⅛″ of water, the Simplex "MO" Meter provides at low cost a responsible guardian of your flow records.



THE SIMPLEX RATE CONTROLLER

Simplex Type "S" Rate of Flow Controllers are of the balanced-valve type. Embodying in its design many unique features resulting in an accuracy of control within ±3% over a 5 to 1 range and of an unrecoverable head loss at the normal rate of less than 6″ of water, the Simplex "A" Controller is available for gravity or pressure filter effluent or wash water service in sizes of from 3″ to 24″. Its simplicity of design and its arrangement of working parts make the "A" Controller readily adaptable for clear well, filter, table or master control. The "A" Controller is also available for vertical installation, providing a means of reducing in many instances initial plant construction costs by effecting saving in piping and excavation. The direct-acting features of the Simplex Controller insure its operation at all times without the necessity of providing an outside source of power, thus resulting in lower first cost and in less maintenance and operating difficulties.

PROPELLER-TYPE METERS

For Main-Line Metering

JAMES M. MONTGOMERY, Consulting Engineer*
Los Angeles, Calif.

THE principle of the current meter has been used as a primary metering element for the measurement of stream flows for over thirty years. During the past fifteen years this same current meter principle has been applied as a primary element for the measurement of main-line flows by R. W. Sparling, of Los Angeles, and has proven itself well suited for this purpose.

The Propeller-Meter

The propeller-type meter, as illustrated in Figure I, is made up of a six-bladed propeller approximately eight-tenths of the pipe diameter mounted transversely in the center of the pipe. The propeller is made of a plastic material, having a specific gravity of approximately one, and is suitable for use in either cold water or hot water up to 300° F. The propeller practically displaces its own weight in water and is mounted on ball bearings which allow it to rotate freely in the stream of water.

Calibration

Experiments and experience have shown that a propeller will rotate in direct proportion to the velocity of water in a pipe at all flows above an approximate pipe velocity of one-half linear foot per second. The index, or the number of cubic feet passing through the pipe for each turn of the meter shaft, is determined from volumetric tests. From this index proper gears are furnished for direct totalization of the flow.

Characteristics

The current metering principle has certain characteristics that make it particularly well adapted for main-line measurement, as the action of the propeller is solely dependent upon the velocity of flow in the line. The pressure requirement is only such as to always maintain a full pipe of water. The loss of pressure caused by the metering element in sizes 6" and larger does not exceed six (6) inches of water at normal maximum pipe velocity.

Continued accuracy of the current type meter is dependent chiefly upon maintaining a clean metering section and a propeller free from incrustation. The plastic propeller has proven itself well suited for this purpose as it is practically inert and will resist both corrosion and electrolytic action. In order to maintain a uniform meter section the propeller assembly may be mounted in either a cast-iron or steel tube having a bronze liner.

Installation

The metering element may be installed directly on existing pipe lines by means of a saddle either bolted or welded directly on the main. In such installations it is important that the inside diameter of the pipe be accurately determined. In all installations the meterhead may be removed from the pipe line very quickly and easily and it is normally good practice in sizes 12" and smaller to make a yearly inspection and sizes 16" and larger, every five years.

In selecting the proper location for the metering element it should be kept in mind that a normal flow of water, free from either spiralling or jet action, is required for accurate results. The spiralling effect that may be caused in a flow of water passing through a series of elbows, can be largely corrected by installing straightening vanes in the line preceding the meter.

Various forms of such vanes are in use but a very simple and effective correction may be made by the installation of three vanes — each approximately one-third the pipe diameter and two and one-half pipe diameters long, set at 120 degrees to each other in the pipe. These vanes will not eliminate a disturbance caused by a partially open gate-valve, but are effective for double elbows or other standard fittings and with such vanes the meter element may be installed with but two pipe diameters of straight approach.

One pipe diameter downstream is normally sufficient for all installations. Unless approximately ten pipe diameters are available ahead of the meter, it is always good practice to use the straightening vanes. When the metering element is installed complete, with either a flange or bell and spigot tube, the three vanes mounted directly inside this metering section constitutes a complete unit ready for installation.

The metering element can be installed in either a vertical or horizontal pipe line and is suitable for mounting on either the suction or discharge side of a centrifugal pump.

Compound Design

Figure II is a sectional illustration of a compound meter suitable for use where an extremely wide range of flow measurement is required. A range of 150 to 1 is possible. A compound unit consists chiefly of two propeller-type meters working in series

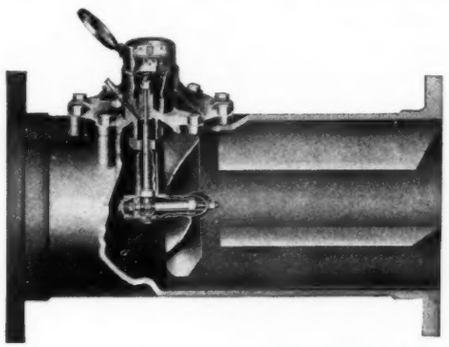


Fig. I—Cutaway View of Propeller Meter Note the flow straightening vanes in the tube, the whole unit ready for insertion as a single piece in the main-line.

through a pair of rachet clutches, allowing the meter revolving at the highest speed to drive the totalizing register. On the very low flows the large meter will under-register and thus allow the small meter to drive the totalizer. As the flows increase a pipe velocity is reached where the large meter has come into step and the small meter is operating at a high capacity. At this point the pressure loss caused by the small meter operating on the differential area of the compounding valve forces the valve to lift itself and allow the higher flow to by-pass the small meter.

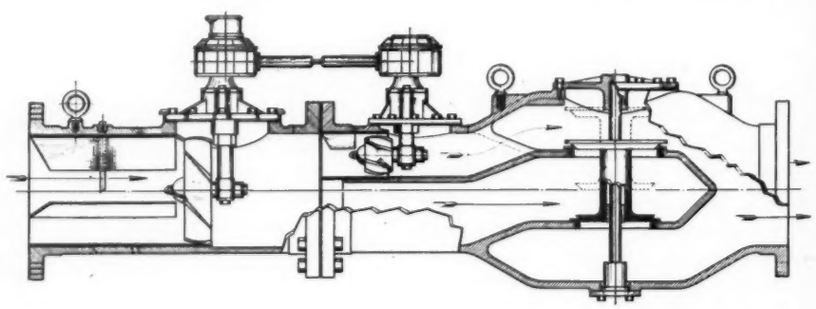


Fig. II—Section Through Propeller-Type Compound Meter Note valve which closes on low flows to cause entire flow to pass through small meter.

Although the minimum flow is considerably above that of the standard domestic compound meter it is well adapted for main-line measurement as the pressure loss caused by the entire unit does not normally exceed two pounds at maximum flow.

*President, J. M. Montgomery & Co., Engineer.

Indicating and Recording Elements

A rate-of-flow indicating and recording instrument may be used in conjunction with the straight totalizing primary element. The primary step of a current type meter is direct totalization. If the rate-of-flow indication is desired it must be obtained through a secondary step normally involving either a governor bowl or a friction plate revolving at a constant speed with a follower locating itself on the plate by impulses from the primary element.

Figure III illustrates the recording instrument involving a governor bowl which is driven either mechanically up to 15 feet from the metering element, or electrically to any distance required. The governor bowl consists chiefly of a float riding in the center of a mercury well. As the governor revolves, the mercury, through centrifugal force, finds its way through a small needle-valve to the outer chamber of the bowl, allowing the float in the center to have a rising and falling action in proportion to the revolving

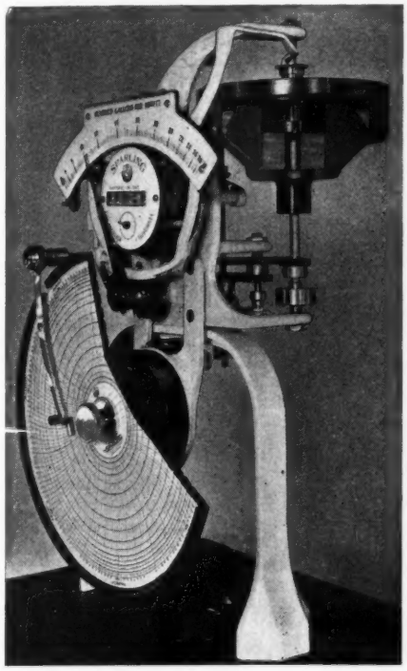


Fig. III—Typical Sparling Indicator-Recorder of the Mercury Governor Type.

speed of the bowl. This type of governor is effective over approximately a 6-to-1 range and is extremely simple and well suited for normal pump like measurement.

A recording instrument utilizing the revolving friction plate, with a follower locating itself by impulses from the metering element, as mentioned above, produces a straight line of rate indication over approximately 25-to-1 range and is well suited for recording flows of main distribution or consumption lines.

Recorders can be adapted to show the combined flows of two or more pipe lines and combinations may be furnished showing the net total of several lines where the flow of any one pipe may be in either forward or reverse direction.

Application in Chemical Feed Control

Automatic control of chemical feeders by either mechanical or electrical means is readily obtainable from a current meter element as the shaft of the meter is revolving in direct proportion to the flow and considerable load may be applied without affecting the rotating speed of the propeller.

If given the periodic inspection required by any primary metering element, the characteristic of low pressure loss and accuracy over a wide range of flow allows the principle of the current meter to fill an important part in the waterworks field.

The propeller-type meter is not suitable for measuring raw sewage and is not generally recommended for measurement of a sewage effluent unless it has passed through a filter bed. Care must also be taken when installing such meters on raw water gravity lines that screens are provided at the inlet structure to prevent excessive algae or weeds from passing down the pipe and stalling the meter propeller.

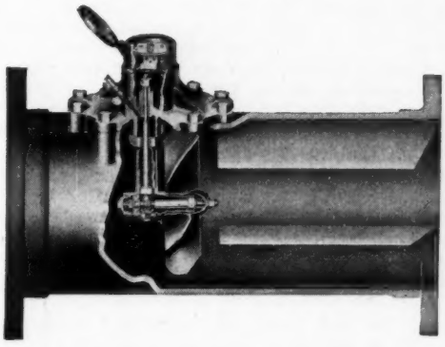
R. W. SPARLING

Manufacturers of

MAIN - LINE WATER MEASURING EQUIPMENT

LOS ANGELES Box 3277 Terminal Annex
CHICAGO 3104 S. Michigan Avenue
CINCINNATI 622 Broadway
NEW YORK 101 Park Avenue

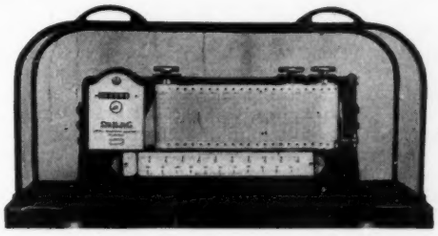
The "Direct Action" Meter



Every Sparling Main-Line Meter is a *complete* Totalizing unit, operated by the action of water flowing through a propeller, such as is shown in the cutaway view above. Shafts and gears carry the revolutions directly to the register. All Sparling Meters are triple-tested for accuracy within 2 per cent before shipment. Flanged or bell and spigot tube meters are available from 2″ to 36″; threaded tubes, 2″ to 6″. Saddle type meters are sometimes preferred for mounting on lines already in service.

If Totalization is all you need, that is all you pay for. Indicating and recording instruments can be added if, as and when desired.

1-Day, 7-Day, 60-Day Records



The recorder shown above is remote controlled by electrical impulses from the meterhead. It combines a second totalizer, indication of flow-rate in two equivalent rates, and complete record of deliveries for periods up to 60 days . . . with past 15 hours on view.

Another type of Totalizer-Indicator-Recorder operates (within 15 feet of the meterhead) independent of electric power. At greater distances by electric remote control. This type uses circular charts for 24-hour or 7-day records. Pedestal, wall and panel mountings are available.

Auto-Metered Chemical Feeding

Adjusting chemical feed to changing flows is simplified with Sparling Auto-Metered Controls. One type, often used with chlorinators, is purely mechanical. Another relays electric impulses and this installation may include a Variator, so that by the twist of a knob, the proportion of chemicals fed to the flow may be increased or decreased over a 20 to 100 range.

Sparling Compound Meters accurately register flows over a range as wide as 1 to 120.

Bulletin No. 308 will be sent upon request.

RESISTANCE OF VALVES AND FITTINGS TO FLOW OF WATER

When the flow of a fluid in a pipe line is altered by some obstruction such as a valve or fitting, the velocity is changed, turbulence is magnified and a drop in pressure results. This pressure drop may be insignificant in long lines where it is very small in comparison to the total drop, but when the line is short the pressure drop through valves and fittings becomes a major item in the total pressure drop value.

The most widely used data on the subject of the resistance of valves and fittings to the flow of water and steam is the information given in Dean Foster's paper on "Effect of Fittings on Flow of Fluids Through Pipe Lines" published in Vol. 42, 1920, of the Transactions of the American Society of Mechanical Engineers. Recently, tests conducted by others have indicated that the values given by Foster are low for globe valves, angle valves, etc., and that data is needed to establish the correct information to use. It has been the tendency, and probably is the most practical way, to present the friction values in terms of an equivalent length of the same size of pipe; i.e., the pressure drop caused by a 2-inch elbow is equivalent to approximately the pressure drop caused by five or six feet of 2-inch pipe under the same conditions of flow.

Realizing the need for definite data covering this subject, Crane Co. has recently conducted pressure drop tests on valves and fittings on both water and steam. These tests were made on 2 inch and 6 inch sizes and conducted under conditions which were thoroughly investigated previous to the tests. The results of these tests are presented herewith together with a description of the method used in conducting them.

[*Note.*—Water and steam can be treated comparatively and a relation can be established between the relative friction values of water and steam. Foster has stated that the equivalent length of pipe for steam flow is about .8 of that established for the flow of water.]

Friction Losses of Water Line Valves and Fittings

The tests for determining the pressure drop of valves and fittings installed in a water line were made in the following manner:

A flow nozzle was installed in a 3 in. test line leading from the bottom of a 1,000 gallon water tank. A mercury manometer was set across this nozzle and the relation of mercury deflection to the gallons of water per minute flowing through the pipe was determined. The flow through the pipe was thereafter noted only in terms of mercury deflection which was readily transposed into gallons per minute by reference to the calibration chart.

The valve or fitting to be tested was placed in the line at some distance from the flow nozzle and the flow water through it was regulated by a throttling valve situated at the outlet of the line. The pressure drop was measured by means of a mercury manometer, or where the deflection was too great, by two sensitive low pressure gages, the leads of which were situated in the test line at a distance of ten pipe diameters (20 in.) from each end of the valve or fitting on test. The initial pressure at the inlet of the test line was kept constant at 80 pounds per square inch and the various rates of flow produced by throttling the outlet of the test line.

After the data was obtained the means of presenting it in its best form was investigated. In any pressure drop tabulation, the values for the fittings and valves in the line are added to the pressure drop of the entire length of line. Therefore, it seemed reasonable to disregard the pressure drop caused by the length of the valve or fitting and just list the pressure drop which was added to the line due to the presence of the article.

For instance, if a valve 4 in. face to face is installed in a line 30 in. long, the actual pressure drop through the valve will be the total pressure drop minus the pressure drop caused by 26 in. of pipe. However, in a practical problem this value will be added to the pressure drop caused by the total length of the line which will give a pressure drop value slightly higher than the actual. This may not be so noticeable with one or two valves or fittings in the line, but where the number runs up into 10 or 20 the added drop may be considerable.

This "No-length" concept was established and has been used before with reference to elbows in "The Friction of Water in Pipes and Fittings" by F. E. Giesecke, University of Texas Bulletin No. 1759.

Resistance in Terms of Equivalent Pipe Length

From data given in the tests conducted by Crane Co. and also from information gathered from authentic sources, Fig. 16, has been prepared which gives the equivalent length of pipe to produce the same pressure drop as a valve or fitting. This additional pipe length should be added to the length of the line in order to determine the total pressure drop.

The equivalent length of pipe has been based upon the pressure drop values for the flow of water in pipes and upon the following coefficients of

$$H_1 = k\frac{V^2}{2g}$$

H_1 = Loss of head in ft.
k = Coefficient
V = Vel. in ft. per sec.
$2g = 64.4$

Type	*Coefficient*	*Authority*
Globe valves	10	Crane Tests
Angle Valve	5	Crane Tests
Return Bend	2.2	
Tee	1.8	Giesecke & Bladgett—Texas College
Short Radius Elbow	.9	Giesecke & Bladgett—Texas College
Med. Radius Elbow	.75	& Crane tests
Long Radius Elbow	.60	Bulletin No. 2712—U. of Texas.
Gate Valve (Open)	.19	Bulletin No. 252—U. of Wis. (Av.)
¼ Closed	1.15	Bulletin No. 252—U. of Wis. (Av.)
½ Closed	5.6	Bulletin No. 252—U. of Wis. (Av.)
¾ Closed	24.0	Bulletin No. 252—U. of Wis. (Av.)
Borda Entrance	.83	"Hydraulic" Daugherty (Average)
Sudden Enlargement		
d/D — ¼	.92	"Hydraulics" Daugherty
d/D — ½	.56	"Hydraulics" Daugherty
d/D — ¾	.19	"Hydraulics" Daugherty
Ordinary Entrance	.5	"Hydraulics" Daugherty
Sudden Contraction		
4/D = ¼	.42	"Hydraulics" Daugherty
d/D = ½	.33	"Hydraulics" Daugherty
d/D = ¾	.19	"Hydraulics" Daugherty
45° Elbow	.42	Bulletin No. 2712U. of Texas

***From Crane Co.'s "Engineering Data on Flow of Fluids in Pipes"—Technical Bulletin No. 405—1935. Parts dealing with steam pressure losses have been omitted.—Ed.**

AGE FACTORS[3]

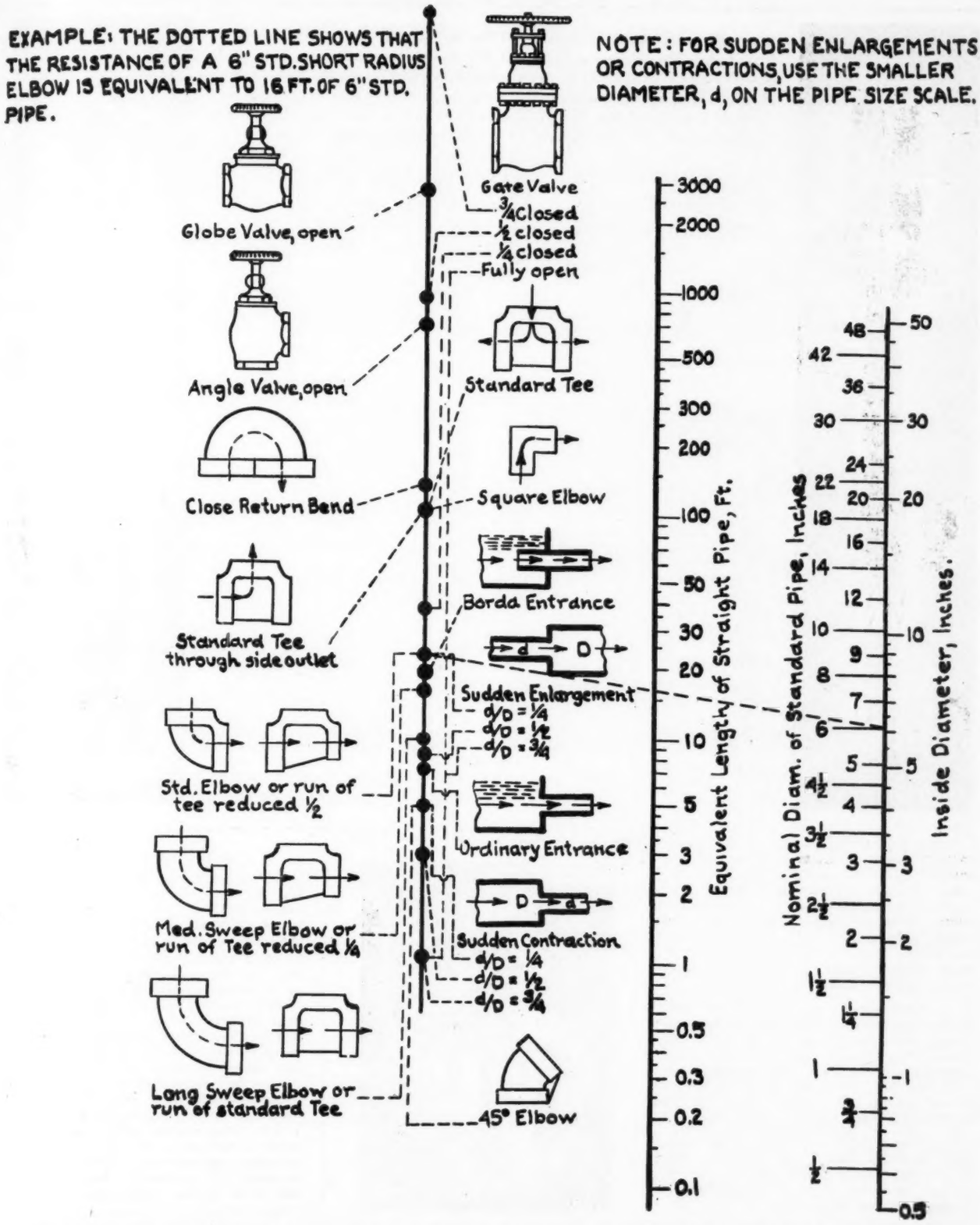
	Age in Years						
	New	10	15	20	30	50	75
Fire Protection Mains							
No Domestic Draft	0.7	0.9	1.0	1.1	1.4	1.8	2.3
Public and Fire Protection Mains with Domestic Draft							
Surface Water							
Slight Tuberculation	0.7	0.9	1.0	1.1	1.4	1.8	2.3
Moderate Tuberculation	0.7	1.2	1.7	2.1	2.9	3.5	3.9
Severe Tuberculation	0.7	1.6	2.4	3.1	4.5	5.2	5.5
Well Water	0.7	1.6	2.4	3.1	4.5	5.2	5.5

These age factors for cast-iron mains are adapted from the results of an investigation by a committee of the New England Water Works Association and reported in their Proceedings, Vol. XLIX, No. 3, September, 1935.

*[In using chart on oposite page in conjunction with C.I. pipe, apply these age factors as directed in footnote.]

FRICTION CHART FOR VALVES AND FITTINGS

For Converting These Units Into Equivalent Added Length of Pipe*



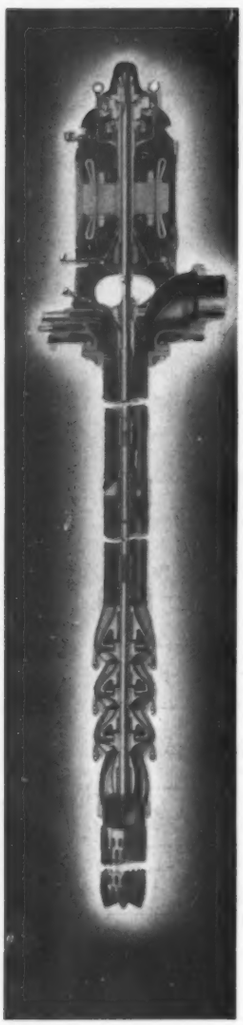
Note: These equivalents, in terms of length of pipe to be added in computations, were derived for steel pipe in goood condition. In applying the chart to cast-iron pipe divide the equivalent length of steel pipe by 1.64 times the most appropriate age factor found in the table of C.I. pipe values. See bottom of page opposite this.

POMONA PUMP CO.

4301-7 South Spring St.
ST. LOUIS, MO.

120 Broadway
NEW YORK, N. Y.

206 East Commercial St.
POMONA, CALIF.



Every Pomona pump is engineered for the specific duty for which it is intended. Therefore, only a general description of type, size and characteristics can possibly be included here. However, trained hydraulic engineers are available at your nearby Pomona distributor to quickly furnish detailed information, proposals, etc., to meet your specific needs. Or write direct to the nearest main office listed above.

POMONA DEEP WELL TURBINE PUMPS

For primary water supply; for all industrial, municipal, mining and agricultural purposes. Adaptable as boosters, for circulation, cooling, air conditioning, fire protection and other similar purposes.

Open drive shaft construction; cutless rubber bearings revolving in patented bronze bearing retainers; water lubricated, assuring delivery of water at the pump head as clean and uncontaminated as at the bottom of the well; semi-open impellers, adjustable for capacity from the top of the pump; fully accessible above-ground packing gland; bowls of Pomoloy high tensile strength cast iron; special column pipe and couplings made to precision specifications to assure correct alignment of pump shaft.

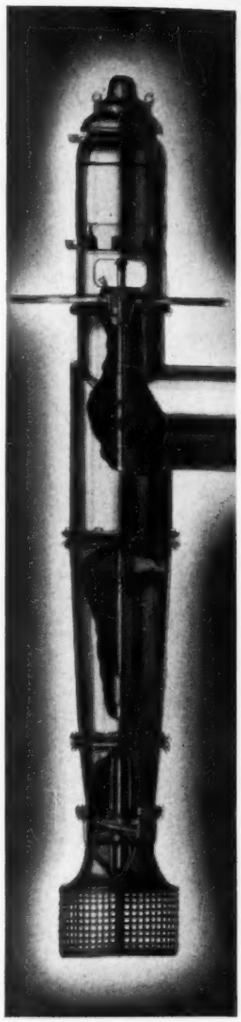
Sizes from 4 to 24 in. or larger; from single stage to multi-staging; from 1½ to 1000 hp.; capacities from 15 to 10,000 g.p.m.; for lifts against pressures up to 800 p.s.i; for temperatures to 180° F.

POMONA NIAGARA PUMPS

(*Right*) Adaptable for condenser circulation and cooling, for transferring large volumes of liquids quickly, for washing and flushing processes (hot or cold), for agitating liquids and semi-liquids in process vats, for dry docks (main and trimming pumps), for pumping out caissons, for check and coffer dams, for storm water drainage, for treated sewage, for handling raw water from lakes and rivers into treating plants, for irrigation, flood control service or storm water drainage.

Open drive shaft construction (cold rolled Monel, stainless, chrome plated, Herculoy, Yoloy, and special analysis steels); cutless rubber, Duprene or special bearings; self-lubricated by fluid being pumped; semi-open impellers, adjustable capacity; bowls of Pomoloy iron, alloy iron, brass, the alloy bronzes, or other special materials; fabricated column and directed flow type elbow from mild steel, Corten low alloy, or other special corrosion resisting plate.

Definitely advantageous for large gallonage low lift operations; compact; no priming requirement. Available in two types—Niagara propeller for relatively low heads and Niagara mixflow for lifts up to 90 ft. Niagara propeller has same characteristics as ship propeller and operates in bowl assembly with suitable guide vanes. Mixflow bowl assembly has impeller possessing both axial flow and centrifugal component. Capacities range from 1,000 to 100,000 g.p.m.; for fluid temperatures to 180° F.

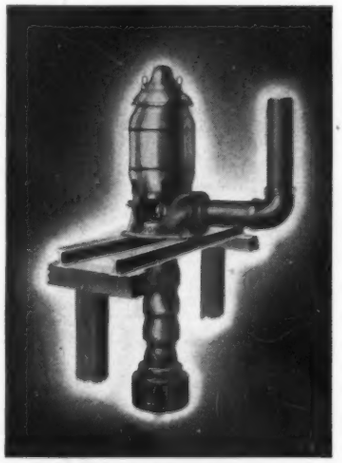


POMONA INDUSTRIAL PUMPS

(*Right*) Adaptable for condenser pumping, booster pumps, transfer pumps, circulation pumps, agitation pumps, vat and sump pumps, vacuum lift pressure pumps, vacuprocess sinking pumps, caisson dewatering pumps, dredge transfer pumps, air conditioning pumps, wash water pumps for washing filters, water works and sewage treatment pumps, waste disposal plant pumps, fire protection pumps, etc.

Open drive shaft construction (cold rolled Monel, stainless, chrome plated, Herculoy, Yoloy, and special analysis steels); cutless rubber, Duprene or special bearings; self-lubricated by the fluid being pumped; semi-open impellers, adjustable capacity; bowls of Pomoloy iron, alloy iron, brass, the alloy bronzes, or other special materials.

Sizes from 4 to 24 in.; from single stage to multi-staging; from 1½ to 1000 hp.; capacities from 15 to 10,000 g.p.m.; for lifts against pressures up to 800 p.s.i; for fluid temperatures to 180° F.



IMPORTANT

In Pomona Pumps ALL bearings below the motor head are *completely* lubricated by the water being pumped. There are no oil or grease chambers in the water stream to require frequent packing . . . no grease ducts or tubes to maintain . . . in fact, no bearings *anywhere* in the water stream that require any type of lubricant whatever, except the water itself. Thus, water pumped by a Pomona is—*and always will be*—as clean and uncontaminated as at the source . . . an important feature that makes these pumps doubly valuable for all municipal water supply applications.

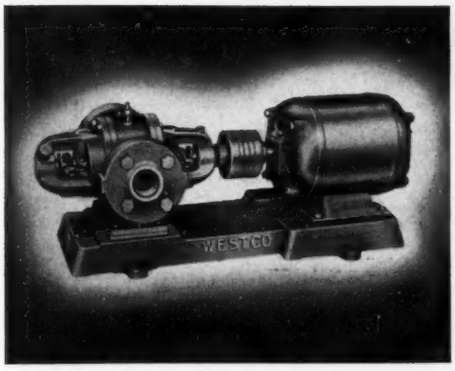
Our engineering staff has had broad experience in all types of pumping applications. It will be glad to study your particular requirements and offer helpful suggestions.

Pomona Pump distribution is nation-wide, with distributors in all principal cities of the United States and in major foreign countries. Write direct for the location of the distributor nearest you. He will be glad to supply detailed information on Pomona Pumps and their outstanding advantages for various water and sewage plant applications.

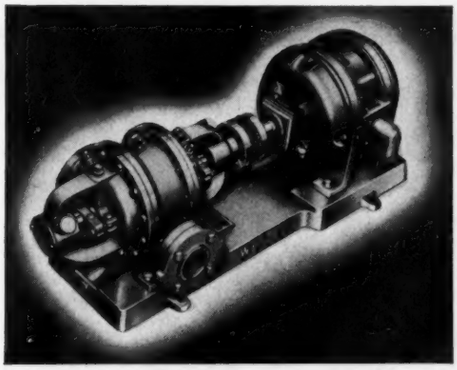
POMONA PUMP CO.

THE ORIGINAL Westco TURBINE PUMP

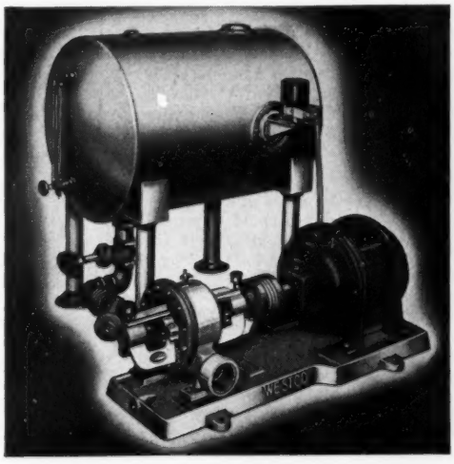
WITH PATENTED RENEWABLE LINERS



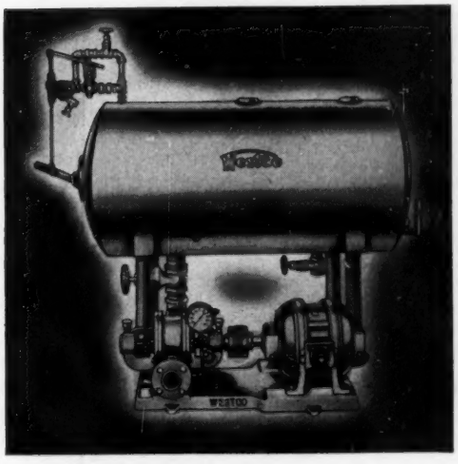
Single Stage Heavy Duty Model for General Industrial Work



Water Cooled Stuffing Box, Single Stage Model



Boiler Feed System



Condensation Return Unit

Westco turbine pumps utilize the same basic principle as that employed in the steam turbine. Liquid entering the pump is picked up by a multi-vaned impeller and carried to the discharge outlet, with each vane imparting additional pressure. Thus multi-stage performance is achieved with a single-stage pump.

Compactly designed and sturdily built, Westco turbine pumps are adaptable for a wide range of industrial uses. Equipped with patented renewable liners, casings are protected against internal wear. Liners consist of two solid inner rings, precision machined to form the liquid channel, and may be quickly and easily replaced without disturbing suction or discharge connections. Double suction inlets provide perfect hydraulic balance, thus eliminating end thrust. Radial load supported by two ball bearing assemblies.

Westco turbine type pumps are capable of delivering viscosities up to 600 s.s.u. and temperatures to 650° F. Tendency to vapor lock is minimized by multi-vaned impeller. Capacities range up to 250 g.p.m., with heads up to 350 feet, single stage, at 1750 r.p.m. Available in both flexible couplings and Uni-bilt styles.

Westco side suction centrifugal type pumps are also available both in the Uni-bilt and flexible coupling styles.

Condensation application range in pressure from 20 to 200 p.s.i. and capacities to 150 g.p.m.

Boiler Feed units cover boiler h.p. ratings from 5 to 750 h.p. and pressures to 200 p.s.i.

Water systems range from ¼ h.p., delivering 360 g.p.h., to 3 h.p., delivering 3000 g.p.h.

Cellar drainers are submerged centrifugal volute type, equipped with ¼ and 1/3 h.p. motors, operating against a discharge head of from 6 to 26 feet and with capacities of from 480 g.p.h. to 3,450 g.p.h.

Westco distributors are located in all principal cities throughout the United States. Write direct for the location of the distributor nearest you. He will be glad to supply detailed information on Pomona Pumps and their application to various water and sewage plant operations.

BARRETT, HAENTJENS & CO.

Hazleton
PENNSYLVANIA

Hazleton Type "M" Check Valve with Built-in Mercoid Motor Shut-off Switch for Automatic Pump Protection

PROTECTS PUMP FROM DAMAGE DUE TO LOSS OF WATER

PREVENTS OPERATION OF PUMP UNTIL PROPERLY PRIMED

The purpose of the flow switch is to insure pump against damage in the event that the pump loses its water during operation. The mercoid switch is actuated by the valve flap. Normally the switch is open when the flap is down. When the pump delivers water, the flow through the valve raises the flap and closes the switch. The mercoid switch is connected into the no-voltage coil of the motor starter.

When using a hand starter, the pump can be started up by hand, whether delivering water or not, but when the hand is removed from the starting lever, the pump will immediately stop unless the pump is delivering water and the mercoid switch of the check valve closed. With an automatic starter the "start" push button must be held in until the pump delivers water and closes the check valve switch.

Let us quote on your requirements

CENTRIFUGAL PUMPS*

Some Notes on Selection of the Proper Pump and A Simple Method of Checking Pump Efficiencies

By H. E. BECKWITH, Engineer
The Pitometer Company
New York, N. Y.

SOME twenty years ago when I first entered the water works field steam driven displacement type pumps were in general use. But, today we find the great majority of pumping stations equipped with electrically driven centrifugal pumps, with an occasional Diesel driven or turbine driven centrifugal installation. The old slow moving reciprocating pump of yesterday could always be depended upon to take care of changing pumping loads and varying heads without any great loss in efficiency. But, this is decidedly not so with the modern centrifugal pump, designed to work under rather fixed conditions. Any appreciable variation from these conditions is accompanied by a falling off in efficiency, which may be rather marked.

Unfortunately, the non-technical water works operator who got his early practical experience with the old displacement type of pump has not always become sufficiently acquainted with the characteristics of the centrifugal pump. Only too often the only demand made on a centrifugal pump is that it pump water, and little or no attention is paid to the efficiency with which it does its work. In fact the average water works man is usually not acquainted with any simple method of determining this efficiency.

It is, therefore, the purpose of this article to point out the conditions which may be expected to cause low operating efficiency, and to outline a simple method for testing the wire-to-water efficiency which gives results as close as is necessary in practical water works operation.

Basic Principles of the Centrifugal

As a youngster I used to tie a chestnut on the end of a string and whirl it around my head until I had imparted to it the force necessary to take it flying through the air at high speed. You did it, too. The principle of building up velocity of that chestnut by whirling it about the head is the same principle which is used in the design of a centrifugal pump. The water which enters the pump through the suction inlet is seized by the rotating vanes of the impeller and spun until it is rotating at terrific velocity. Since pressure and not velocity is desired, the pump is so designed that by gradually slowing down this velocity in the casing of the pump, the energy stored up in this rapidly moving water is almost entirely changed to pressure. The speed of the chestnut rests upon two factors—the length of the string and the number of revolutions made within a specified period of time. The speed, and hence the resulting pressure, imparted to water by a centrifugal pump also rests upon the same two factors—the diameter of the impeller and the number of revolutions per minute which the impeller makes.

There are, of course, practical limits to both the speed and the diameter so that it is not always possible to secure the full desired pressure with one pump. If not, the water is passed through two or more pumps in series, and each pump raises the pressure part of the total desired amount. Sometimes these two or more pumps are built in one pump case, in which instance each pump is called a "stage" Since electrically driven centrifugal pumps operate at fixed speeds, there is always one head under which a pump will operate most efficiently. Right here it will not hurt to repeat that any material deviation from this condition will result in decreased efficiency.

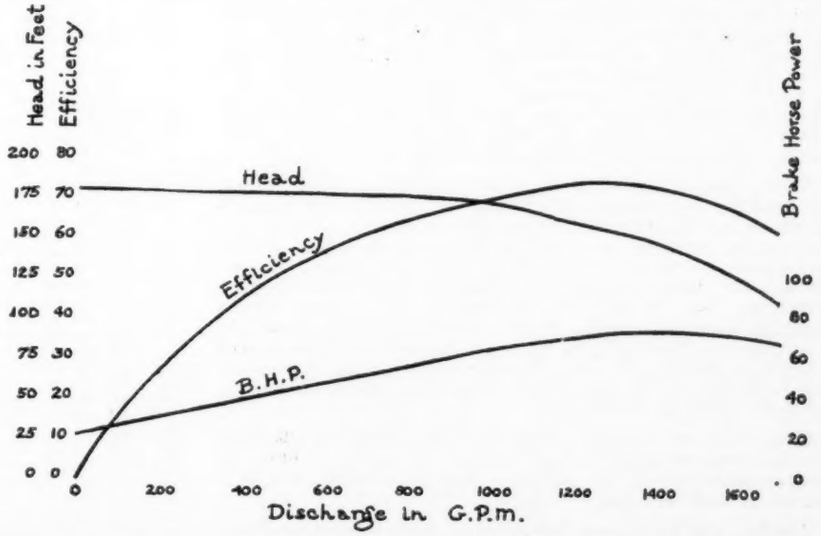
Pump Performance Curves

At this point I want to introduce a typical centrifugal pump curve which we will use for illustration during this discussion. Similar curves are available from the manufacturer for all medium sized and large pumps. On small pumps it is not customary to furnish such performance curves.

It will be noted from an inspection of the specimen curve that the greatest efficiency for this particular pump (about 75%) is secured when the head is about 155 ft. and the discharge rate is about 1,300 G.P.M. You will also note that as the head is materially increased or decreased from the optimum head there is a large change in the pumping rate and a considerable drop in efficiency. A great deal has been done in design effort to widen out the "peak" of the efficiency curve into a "plateau" so as to give high efficiencies for centrifugal pumps under a wider range of operating conditions. Considerable progress has been made in this direction.

Friction Head—Its Importance

Let us see what happens when we forget to include pipe friction loss when figuring the total head against which the pump must operate. If we have figured on the pump whose curve we have, and if we are pumping through two miles of 16" main, the friction loss will add about 18 ft. to the pumping head—making it 173 ft. At this head (see curves) the pumping rate will drop to 1,000 G.P.M. and the efficiency to 70%. Furthermore, the pump is operating on a very critical part of the curve where a slight increase in pumping head—caused by tuberculation in the main or by any other reason—would incur a precipitate drop in both the efficiency and the pumping rate. It also illustrates what can happen to a pump, after installation, when the pumping head has been increased above the head for which it was designed. As



An Example of Typical Performance Curves for Centrifugal Pumps. Various designs show individual characteristics in respect to the curves produced.

* Excerpts from a paper presented before the Penna. Water Operators Association and an earlier article by Mr. Beckwith in previous Reference & Data Issues of this magazine.

it is the nature of unlined iron and steel mains to tuberculate, resulting in a constantly rising friction loss, this is an important consideration.

Let us illustrate this in another way.

Selecting the Right Pump

Suppose that we are in the market for a 1,000 G.P.M. pump operating against a total head of 173 ft., and a pump whose curve we have been using has been submitted for consideration. I would not consider this pump a good "buy" to operate under these conditions. In the first place it will be noted that the efficiency of 70% is much below the maximum efficiency of 75%. But even more important, perhaps, is the fact that the pump at 173 ft. head is operating under "critical head" conditions. An increase of only about 8 ft. (less than 5%) in the pumping head would bring the head to the maximum which the pump can create—in other words to the "cut off" point. This means that an increase in the head of only 8 ft. (about 3½ pounds) would decrease the pumping rate from 1,000 G.P.M. to zero G.P.M. Moreover an increase of only 3 ft. in head would cause a drop of 200 G.P.M. in the pumping rate. On the other hand, when we are working in the most efficient range of the pump a change of 3 ft. in the head would only cause a variation of 30 to 40 G.P.M. in the pumping rate; and, the efficiency is practically unaffected.

It follows, therefore, that one should buy a pump within the range where the efficiency curve is as *flat* as possible and the head curve is as *steep* as possible. In this connection a word of warning may not be amiss. By making the vertical scale of the curve less than is customary, a much flatter *appearing* efficiency curve can be secured. So in comparing the performance curves of pumps be sure that they are plotted on comparable scales. I have known curves with reduced vertical scales to be submitted where I felt sure that the scale was deliberately reduced for the purpose of deception.

Mistaken Economy

Only too often in the revamping of a plant, efforts are made to re-use as much of the old equipment as possible. It may be assumed that if the old pump will handle 1,300 G.P.M. against 155 ft. of head it should have less trouble pumping the same amount from the river to the settling basin against a head of only forty or fifty feet. This is so. In fact, if we will look at the curve we will find it will pump much more than 1,300 G.P.M. at the lower head. The curve does not go out that far, but it goes far enough to show what would happen—not only to the pumping rate but to the efficiency as well. The pumping *rate goes up* but the *efficiency goes down*—yes, way down. Reducing the head has a tendency to cause a pump to run away much as an automobile would run away down hill when the going becomes easier if the throttle were not closed to compensate for the decreased demand for power. This running away of the pump sometimes overloads the motor so that it runs hot. To prevent this, operators raise the head artificially by partly closing a valve on the outlet side of the pump. This decreases the load on the motor and brings the pumping rate back to normal. But it burns up a great deal of power needlessly as the closed valve destroys part of the head generated by the pump and only part of the work actually performed is effective. I have known of installations, such as this, where the installation of a new pump saved more than enough power in one year to pay the entire cost of the new pump and motor and also completely depreciate the old unit replaced.

But it is not always necessary to buy a new pump just because the head has been reduced. If we will get back to that chestnut on the string we will find that we can reduce the speed of the chestnut by reducing the length of the string, at the same time keeping the number of revolutions constant. In the same manner, we can cut down the pressure generated by a constant speed centrifugal pump by reducing the diameter of the runner. If the reduction in head is moderate, the manufacturer can advise you how much will have to be machined off the outside of the present impeller so that it will pump efficiently, or at a slight expense he will furnish a new impeller for the changed conditions. Or he may cut down your old impeller.

It is sometimes possible to secure a larger impeller to efficiently handle increased heads, but in this case the motor is likely to be overloaded unless the original specification anticipated such change as loads increased.

Another way to increase the speed of that chestnut would be to keep the length of the string constant and to increase the number of revolutions. It follows that if we increase the revolutions of any centrifugal pump we will increase the head which that pump will generate. This explains why a certain pump tested last fall gave a wire to water efficiency of only 40%. This pump was designed for use with a gasoline motor and to operate under the then existing head conditions at a speed of 1400 R.P.M. Eventually electric power became available and the pump was connected to an electric motor and the speed increased to 1,800 R.P.M. This, of course, increased the head generated by the pump itself, and the efficiency was consequently very low.

A somewhat similar condition was found several years ago when a 5 M.G.D. installation designed to work against a head of 100 pounds was found to have been connected in series to a 5 M.G.D. pump designed to pump against 50 pounds pressure. This gave an installation with a design head of 150 pounds, but the actual head was still only about 100 pounds. The *output* was thereby *increased* to approximately 6 M.G.D. but the *efficiency decreased* to the point where it was only slightly above 40%. New and properly designed equipment brought the wire-to-water efficiency up to about 75%.

It can be readily seen from the above considerations that the chances of buying a suitable pump from the "junk man" are just about nil. It might be "as good as new" for the conditions for which it was designed and yet be absolutely worthless under any other conditions. In fact, it would probably be a most expensive liability. Yet pumps have been bought from the equivalent of "junk men", but most frequently have been "salvaged" by the original purchaser for other duty than originally purchased for.

So far, we have been discussing equipment which has been working under conditions which made it impossible to give a creditable showing. A mere inspection of the conditions and a knowledge of the design limitations would make it evident that satisfactory performance under these conditions could not be secured. However, there are occasions where, after installation, things happen to properly selected pumps which will cut the efficiency of the equipment. There was, for instance, the time

Table I—Gallons of Water Delivered per Kilowatt Hour Against Various Heads on Theoretical Assumption That Pump and Motor Are 100 Per Cent Efficient

H = head in feet. G = gallons per kilowatt hour

H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G
1	318,200	51	6,240	101	3,151	151	2,108	201	1,583	251	1,268	301	1,058	351	907	401	794	451	706
2	159,100	52	6,120	102	3,120	152	2,094	202	1,575	252	1,263	302	1,054	352	904	402	792	452	704
3	106,100	53	6,005	103	3,090	153	2,080	203	1,567	253	1,258	303	1,051	353	902	403	790	453	703
4	79,560	54	5,894	104	3,060	154	2,067	204	1,560	254	1,253	304	1,047	354	899	404	788	454	701
5	63,650	55	5,786	105	3,031	155	2,053	205	1,552	255	1,248	305	1,044	355	897	405	786	455	700
6	53,040	56	5,683	106	3,002	156	2,040	206	1,545	256	1,243	306	1,040	356	894	406	784	456	698
7	45,460	57	5,583	107	2,974	157	2,027	207	1,537	257	1,239	307	1,037	357	892	407	782	457	697
8	39,780	58	5,487	108	2,947	158	2,014	208	1,530	258	1,234	308	1,033	358	889	408	780	458	695
9	35,360	59	5,394	109	2,920	159	2,002	209	1,523	259	1,229	309	1,030	359	887	409	778	459	694
10	31,830	60	5,304	110	2,893	160	1,989	210	1,516	260	1,224	310	1,027	360	884	410	776	460	692
11	28,930	61	5,217	111	2,867	161	1,977	211	1,508	261	1,220	311	1,024	361	882	411	775	461	691
12	26,520	62	5,133	112	2,842	162	1,965	212	1,501	262	1,215	312	1,020	362	879	412	773	462	689
13	24,480	63	5,051	113	2,816	163	1,952	213	1,494	263	1,211	313	1,017	363	877	413	771	463	687
14	22,730	64	4,972	114	2,794	164	1,940	214	1,487	264	1,206	314	1,014	364	875	414	769	464	686
15	21,220	65	4,896	115	2,766	165	1,929	215	1,480	265	1,202	315	1,011	365	873	415	767	465	685
16	19,890	66	4,822	116	2,744	166	1,917	216	1,474	266	1,197	316	1,007	366	870	416	765	466	683
17	18,720	67	4,750	117	2,720	167	1,906	217	1,467	267	1,193	317	1,004	367	868	417	763	467	682
18	17,680	68	4,680	118	2,697	168	1,894	218	1,460	268	1,188	318	1,001	368	865	418	761	468	680
19	16,750	69	4,611	119	2,674	169	1,883	219	1,453	269	1,184	319	998	369	863	419	760	469	679
20	15,910	70	4,547	120	2,652	170	1,872	220	1,447	270	1,179	320	995	370	860	420	758	470	677
21	15,150	71	4,482	121	2,630	171	1,861	221	1,440	271	1,175	321	992	371	858	421	756	471	676
22	14,470	72	4,420	122	2,609	172	1,851	222	1,434	272	1,170	322	989	372	856	422	754	472	675
23	13,830	73	4,360	123	2,588	173	1,840	223	1,427	273	1,168	323	986	373	854	423	753	473	674
24	13,260	74	4,301	124	2,567	174	1,829	224	1,421	274	1,162	324	982	374	851	424	751	474	672
25	12,730	75	4,243	125	2,546	175	1,819	225	1,414	275	1,158	325	979	375	849	425	749	475	671
26	12,240	76	4,185	126	2,526	176	1,809	226	1,408	276	1,154	326	976	376	847	426	747	476	669
27	11,790	77	4,133	127	2,506	177	1,798	227	1,402	277	1,150	327	973	377	845	427	746	477	668
28	11,370	78	4,080	128	2,486	178	1,788	228	1,396	278	1,146	328	970	378	842	428	744	478	666
29	10,970	79	4,028	129	2,467	179	1,778	229	1,390	279	1,142	329	968	379	840	429	742	479	665
30	10,610	80	3,978	130	2,448	180	1,768	230	1,384	280	1,137	330	965	380	838	430	740	480	663
31	10,270	81	3,929	131	2,429	181	1,758	231	1,378	281	1,133	331	962	381	836	431	739	481	662
32	9,945	82	3,882	132	2,411	182	1,749	232	1,372	282	1,129	332	959	382	833	432	737	482	660
33	9,644	83	3,834	133	2,393	183	1,739	233	1,366	283	1,125	333	956	383	831	433	736	483	659
34	9,360	84	3,789	134	2,375	184	1,729	234	1,360	284	1,121	334	953	384	829	434	734	484	658
35	9,093	85	3,744	135	2,358	185	1,720	235	1,354	285	1,117	335	950	385	827	435	732	485	657
36	8,840	86	3,701	136	2,340	186	1,711	236	1,349	286	1,113	336	947	386	825	436	730	486	655
37	8,601	87	3,658	137	2,323	187	1,702	237	1,343	287	1,109	337	945	387	823	437	729	487	654
38	8,375	88	3,617	138	2,306	188	1,693	238	1,337	288	1,105	338	942	388	820	438	727	488	652
39	8,160	89	3,576	139	2,292	189	1,684	239	1,332	289	1,102	339	939	389	818	439	725	489	651
40	7,956	90	3,536	140	2,274	190	1,675	240	1,326	290	1,098	340	936	390	816	440	723	490	650
41	7,762	91	3,497	141	2,257	191	1,666	241	1,320	291	1,094	341	934	391	814	441	722	491	649
42	7,577	92	3,458	142	2,241	192	1,658	242	1,315	292	1,090	342	931	392	812	442	720	492	647
43	7,401	93	3,422	143	2,225	193	1,649	243	1,310	293	1,087	343	929	393	810	443	719	493	646
44	7,233	94	3,386	144	2,210	194	1,640	244	1,304	294	1,083	344	926	394	807	444	717	494	644
45	7,072	95	3,350	145	2,195	195	1,632	245	1,299	295	1,079	345	923	395	805	445	716	495	643
46	6,916	96	3,315	146	2,180	196	1,624	246	1,294	296	1,075	346	920	396	804	446	714	496	642
47	6,771	97	3,281	147	2,165	197	1,615	247	1,288	297	1,072	347	918	397	802	447	712	497	641
48	6,630	98	3,248	148	2,150	198	1,608	248	1,284	298	1,068	348	915	398	800	448	710	498	639
49	6,495	99	3,215	149	2,136	199	1,600	249	1,278	299	1,065	349	913	399	798	449	709	499	638
50	6,365	100	3,183	150	2,122	200	1,592	250	1,273	300	1,061	350	910	400	796	450	707	500	636

when we found a water snake wrapped around the shaft with the result that the inlet ports were partially cut off and the suction lift increased way beyond the 15 feet maximum for best performance. In another and similar situation blocks of wood were found jammed in the ports. Then there was the time that low efficiency was caused by the blowing of the gasket of a multiple stage pump and the water was short circuiting back from a higher stage to a lower stage. One of our engineers once reported that an efficiency of 20% was caused by the impeller slipping on the shaft.

Two interesting conditions have been found by the author which have no reference to the actual efficiency of the pumps but which were determined as th result of making efficiency tests. In one instance, where the meter through which power was purchased was used to measure the power input, it was found that an apparent low efficiency was caused by this meter being set 20% high. In another instance, a pump was discharging into a closed distribution system. On the basis of the water *actually discharged* into the system (24-hour period) the pump had an efficiency of only 8%. Had a standpipe or reservoir been floating on this system, the same amount of water could have been pumped with about one-eighth the amount of power which was actually used.

So much for the reasons why efficiency tests should be made at intervals.

A Simple Efficiency Test

The writer has worked out a simple method for making efficiency tests which he has been using with satisfactory results for some years.

At one foot of head and 100% efficiency of *both pump and motor* it is theoretically possible to raise 318,200 gallons of water one foot with one KW.H. To determine this theoretical value for any other head, simply divide 318,200 by the head involved. For instance, the value at 150 ft. would be $\frac{318{,}200}{159} = 2{,}002$ gallons per KW.H. In this connection the accompanying "Table of Theoretical Values for Various Heads" may prove helpful in reducing calculations in pump testing. It was prepared by the writer and has appeared in earlier Reference and Data Numbers of WATER WORKS AND SEWERAGE.

To determine the *wire-to-water efficiency* of an installation it is only necessary to divide the actual pumpage per KWH by the theoretical value for the pumping head, as determined from the table. A rough check can be made by dividing the month's pumpage in gallons by the KWH consumed. This gives the gallons actually pumped per KWH.

Test Procedure

With the pump running, determine the total head in feet (including suction) against which the pump works. Divide 318,200 gallons by this total head (as above) to determine the theoretical 100% pumpage per KWH. (Or take the figure from Table 1.) Next divide the actual gallons per KWH by the theoretical gallons per KWH to secure the wire to water efficiency.

To illustrate:

Assume a monthly pumpage of 32,640,000 gallons and a monthly power consumption of 30,200 KWH. Say the total head noted was 220 ft. Dividing 32,640.000 by 30,200 gives an actual pumpage of 1,081 gallons per KWH. Dividing 318,200 by 220 ft. gives a theoretical value of a possible 1,447 gallons per KWH at 100% efficiency (see table). Then;

$$\frac{1{,}081 \text{ (observed)}}{1{,}477 \text{ (theoretical)}} = 74.7\% \text{ overall}$$

wire to water efficiency.

A more accurate method of making the tests is to measure the power input for an hour, or some other convenient period of time. During this period carefully check the output of the pump with any suitable main line meter. Keep a close record also of the discharge pressure and of the suction. The integrations on most electric meters in pumping stations cannot be read closely enough for short tests. However, the power company will furnish the number of watts consumed for each revolution of the disk, and by counting its revolutions for ten or twenty minutes the rate of power input can be closely ascertained. Or the power company can be asked to measure the power by means of special equipment. Where more than one pump is taking power through the master meter at the same time, the latter method is the only feasible one for testing each unit separately.

Securing Total Head

The total head in feet must first be secured. If the pressure gauge reads in pounds, convert to feet by multiplying the pounds of pressure by 2.31 [feet of water head giving one pound gauge pressure]. The suction will probably be expressed in inches of mercury. Convert this to feet of water head by multiplying by 1.13. Also measure the vertical distance between the center of the pressure gauge and the point of suction measurement. The total head then becomes the sum of the following:

Discharge pressure, in feet	xxx
Suction, in feet	xx
Vertical distance pressure gauge is above point of suction measurement, feet	x
Total Head in feet	xxx

Velocity head has been ignored, as it is a small factor for the relatively high heads which usually exist in water works operation.

If water is delivered to the pump under pressure, then the pump will be working against a head equal to the difference between the discharge pressure and the inlet pressure.

From the data secured during the test, determine the gallons delivered per kilowatt hour. As before, divide this by the theoretical value for the head against which the pump was operating. This gives the overall wire-to-water efficiency of the installation.

As an example, let us assume an installation where we secured the following test data:

Power input to motor	90.0 K.W.
Rate of discharge	51,840 gals. per hr.
Delivery per KWH	572 gals.
Pressure	146 lbs. = 337 ft.
Suction	15 ins. = 17 ft.
Difference in gauge elevation	1 ft. = 1 ft.
Total head	355 ft.

Theoretical discharge at 335 ft. head (see table) is $\left(\frac{318{,}200}{355}\right) = 897$ gals.

and

Overall efficiency (wire-to-water) is $\left(\frac{572}{897}\right) = 64\%$

If a suction gauge is not available, an approximation may be secured by measuring the vertical distance from the level of water in the clear well to the center of the pressure gauge, adding to this measured distance about two feet for loss in bends, etc.

What the Tests Reveal

Having shown the desirability of frequent tests and having presented a simple method for making them, it may now be interesting to discuss what these tests may be expected to show. In the first place, there have been great increases in the attainable efficiencies of centrifugal pumps within the past few years. Those of modern design may be expected to give up to the following overall (wire to water) efficiencies.

Capacity G.P.M.	Efficiencies Percent
200	58
400	63
600	68
800	71
1000	73
1500	75
3000	80
5000	82
Over 5000	85

It will be noted that the larger the pump the higher the efficiencies.

There will be variations from these figures depending upon the head and other conditions. Such are submitted only for the purpose of giving something with which to compare the efficiencies of existing installations. This is important, because it will often be found that older equipment may have retained its original efficiency and yet be so inefficient in comparison with modern equipment, now available, that it is decidedly not economical to keep it in operation. It will be worth while to check the present efficiency of every centrifugal pump now more than ten years old, to determine how great a reduction in power consumption can be secured by replacement with more efficient modern pumps.

If an old 1,000 gpm pump, operating at an efficiency of 57%. is replaced with a new pump giving an overall efficiency of 73% You may be surprised.

the same amount of water may be pumped with 22% less power. This means that both the demand rate and the power consumption through each step of the existing rate schedule would be decreased 22%. Such a reduction might prove enough to pay for the new installation in about one year's time. In order to get the gallons per KWH to be expected at any head, for any efficiency, it is only necessary ot determine theoretical gallons per KWH for that head and then to multiply this theoretical value by the expected efficiency. If the total pumpage in gallons is then divided by this expected pumpage per KWH the power consumption to be anticipated from the new installation will be secured. Similarly it is possible to determine the anticipated demand rate, which is often as important (if not more so) than is the total KWH consumption in determining the power bill to be expected from a new installation.

A Worthy Example

In the March, 1939, issue of WATER WORKS AND SEWERAGE an article by Messrs. Marshall and Rawlins of Charlotte, N. C., revealed graphically how the power costs were drastically cut at the local pumping station by replacing old equipment with new. These power costs, which had been running about $16.00 per million gallons were cut to about $7.50 per million gallons. This cut was the result of two definite and distinct improvements. In the first place the pumping main was paralleled with a new line. This resulted in reducing the former friction loss materially. This single betterment cut the power cost from $16.00 to $12.00 per million. Following this, the not very old (but less efficient) pumping units were replaced with modern efficient equipment. This investment, which might appear to the average municipal councilman a questionable expenditure, further reduced the pumping cost to $7.50 per million, representing a very notable day in and day out saving.

Measuring Output of Water

Table I has another use. Many plants, especially smaller ones, have no master meters. With the old displacement type pump it was possible to secure the approximate amount of water pumped by installing a pump stroke counter and multiplying the number of strokes by the discharge in gallons per stroke. If the pump were permitted to get into a state of disrepair, this measurement was apt to be in error, but if the pump were kept in good condition it was reasonably accurate. The method about to be outlined for obtaining the output of water from electrically operated centrifugal pumps has possibly a degree of accuracy comparable to the pump counter method.

From the efficiency curve furnished with the pump, determine the pump efficiency for the head under which the pump operates. The curve will show the pump efficiency only. The combined pump and motor efficiency, the so-called wire to water efficiency, will be about 90 per cent of the efficiency shown for the pump alone. From Table 1 secure the theoretical gallons per kilowatt hour for the head under which the pump is operated. Multiply this by the overall wire to water efficiency just secured. This gives the number of gallons per kilowatt hour the pump should deliver. Multiply this by the total number of kilowatt hours used over any given period of time and the result should be the number of gallons pumped over the sam period. To illustrate:

Assume a pump with an efficiency of 65 per cent operating at a total head of 200 ft. Then 90 per cent of 65 would give an overall wire to water efficiency of 58.5 per cent. If the installation were 100 per cent efficient, Table 1 indicates the discharge would be 1,592 gallons per kilowatt hour. With an overall efficiency of 58.5 per cent the discharge would be 1,592 $\times$ 58.5 per cent, or 931 gal. If the power consumption for the month be 20,000 kilowatt hours. then the total pumpage becomes 20,000 $\times$ 931 or 18,260,000 gal. for the month.

While this method of computing pumpage will not, as a rule, give results as satisfactory as those secured from a master meter, it does give a close approximation in instances where a master meter is not available.

In outlining the tests in this paper it has not been intended to supplant the more detailed methods used by professional engineers, but to make available to the average water works operator a method of checking which will give reasonably accurate results.

TERMINOLOGY IN PUMPING*

Static Head

Static Head is the vertical distance in feet between the free level of the source of supply and the point of free discharge, or to the level of the free surface of the discharge water.

Total Dynamic Head

Total Dynamic Head, as determined on test, where Suction Lift exists, is the reading of a mercury column connected to the suction nozzle of pump, plus the reading of a pressure gauge connected to discharge nozzle of pump, plus vertical distance between point of attachment of mercury column and center of gauge, plus excess, if any, of Velocity Head of discharge over Velocity Head of suction as measured at points where the instruments are attached, plus head of water resting on mercury column, if any.

Total Dynamic Head, as determined on test, where Suction Head exists, is the reading of a gauge attached to the discharge nozzle of pump, minus the reading of gauge connected to the suction nozzle of pump, plus or minus vertical distance between centers of gauges (depending on whether suction gauge is below or above discharge gauge), plus excess, if any, of Velocity Head of discharge over Velocity Head of suction as measured at points where instruments are attached.

Total Dynamic Discharge Head. is the Total Dynamic Head minus Dynamic Suction Lift, or plus Dynamic Suction Head.

Total Dynamic Head is the vertical distance between source of supply and point of discharge when pumping the required capacity, plus Velocity Head, plus friction and entrance losses.

*From "Hydraulic Data," an Ingersoll-Rand Hand-Book.

Suction Lift

Suction Lift exists where the source of supply is below the center of pump.

Static Suction Lift is the vertical distance from the free level of source of supply to center of pump.

Dynamic Suction Lift is the vertical distance from the source of supply, when pumping required capacity, to center of pump, plus Velocity Head, plus entrance, and friction losses; but not including internal pump losses.

Dynamic Suction Lift, as determined on test, is the reading of a mercury column connected to suction nozzle of pump, plus vertical distance between point of attachment of mercury column to center of pump, plus head of water resting on mercury column, if any.

Suction Head

Suction Head (sometimes called Head on Suction), exists when source of supply is above center of pump.

Static Suction Head is the vertical distance from the free level of the source of supply to center of pump.

Dynamic Suction Head is the vertical distance from the source of supply, when pumping at required capacity, to center of pump, minus Velocity Head, minus entrance, and friction losses; but not minus internal pump losses.

Dynamic Suction Head, as determined on test, is the reading of a gauge connected to suction nozzle of pump, minus vertical distance from center of gauge to center of line pump. Suction Head, after deducting the various losses, may be a negative quantity, in which case a condition equivalent to Suction Lift will prevail.

ELIMINATING SURGE TROUBLES ON PUMP DISCHARGE LINES*

By D. M. RADCLIFFE

Engineer, U. S. Engineers' Office, Washington, D. C.

The purpose of this article is to relate a practical means of preventing dangerous surges and water-hammer in water service pipe lines.

There are several means of preventing surges in pipe lines, the best known of which is the surge tank. In most water supply systems it is not practical to provide surge tanks and therefore some other means must be employed if excessive surging is to be eliminated.

A common cause of dangerous water-hammer or surge in pipe lines of water supply systems is failure of the electric power input to motor driven pumping units. This sudden stop in pumping sets up a series of pressure waves or surges in the discharge pipe line. Much has been published with respect to water-hammer and its effects on pipe lines, therefore this article will discuss briefly a practical means of eliminating surge or water-hammer conditions. The method described is in satisfactory operation on the Washington Aqueduct in the city of Washington, D. C.

The Dalecarlia Pumping Station is equipped with nine synchronous motor driven centrifugal pumping units of 10 and 20 m.g.d. capacities. Three discharge pipe lines extend from the station to service reservoirs. One is a 48-inch pipe line, 12,350 feet in length with 110 feet working head; one a 36-inch line, 8,900 feet in length with 220 feet working head; one a 36-inch line, 15,950 feet in length with 340 feet working head. Three pumps are connected into each of these three lines.

Following accepted practice quick closing check valves had been installed in each of the pump discharge lines. Electric power failures, which occur several times each year, proved the cause of excessive and dangerous surges of water-hammer in the discharge lines. Records of the surges were taken on high-speed pressure charts and it was found that the maximum surge pressures recorded were 175 per cent above normal working pressure on each line.

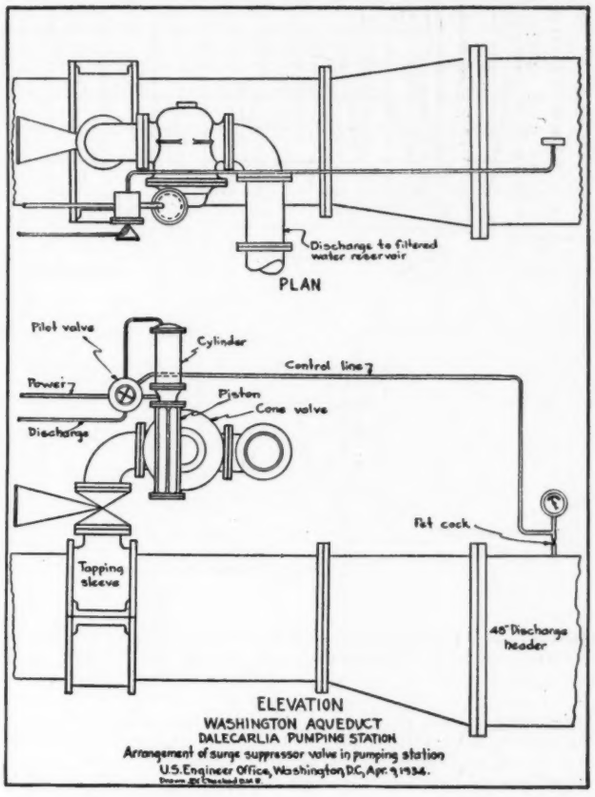


Fig. 2.—Sketch to Show Arrangement of Tapping Sleeve and Surge Relief Valves

Rotary Plug Type Check Valves Installed

After the pumping station had been in opertion for approximately three years, it was decided to install check valves which would reduce to a minimum the loss of head through such valves. The new valves installed are of the rotary plug type and hydraulically operated. These are equipped with an adjustable timing feature to provide means of regulating the speed of closing upon pump shut-down or failure of electric power. Timing tests were made on the new valves to determine, if possible, a closing period which would limit pipe line surges to safe values. A number of closing periods, varying from one second to fifteen seconds, were tried. It was not permissible to employ closing periods in excess of fifteen seconds because a reverse flow of water through the pumps would take place and rotate the units backward at high speed. Since the pumps are not designed for reverse rotation this condition was considered unsafe and time of valve closing was limited to a maximum of fifteen seconds. In the series of closing period tests made, it was found that a five second period produced the best results, but the surge was still 100 per cent above normal working pressure. Unless the check valve can be left open until a surge is dissipated and then closed slowly, it is necessary to close the valve before the first supernormal return wave reaches the station or valve. In the case of the Dalecarlia Station, the first

*From WATER WORKS AND SEWERAGE

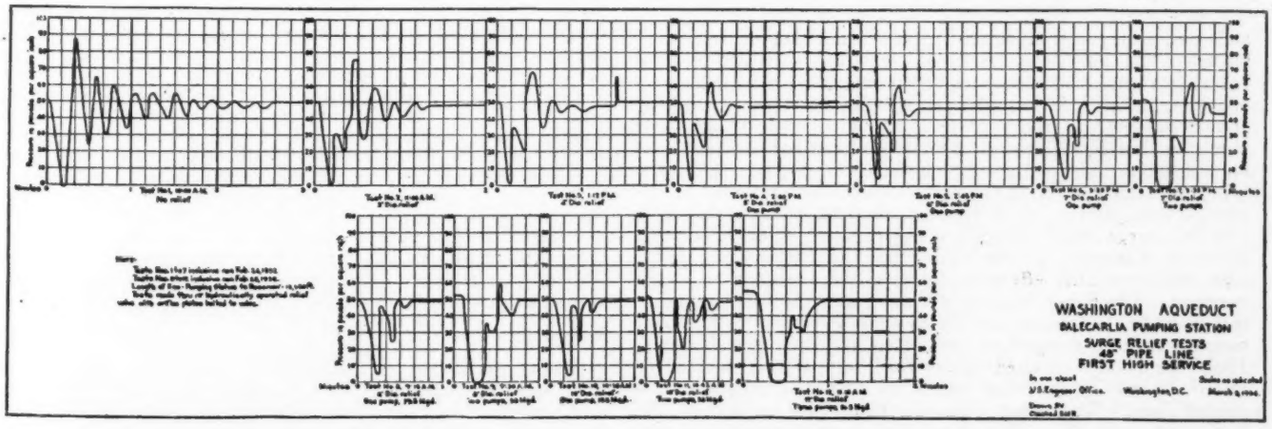


Fig. 1.—Results from Surge Relief Experiments, Employing Various Sizes of Relief Orifice

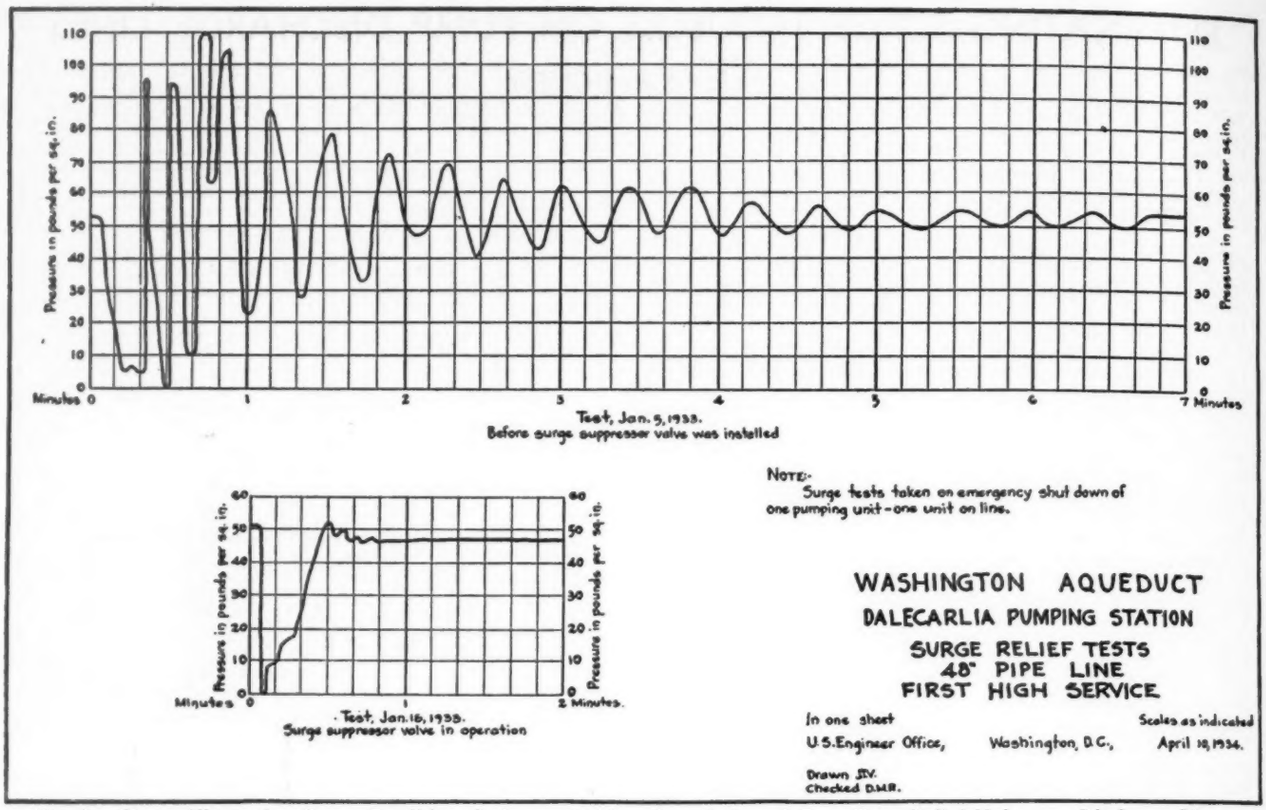

Pressure in pounds per sq. in.
Minutes
Test, Jan. 5, 1933.
Before surge suppressor valve was installed
Test, Jan. 16, 1933.
Surge suppressor valve in operation
NOTE:
Surge tests taken on emergency shut down of one pumping unit - one unit on line.
WASHINGTON AQUEDUCT
DALECARLIA PUMPING STATION
SURGE RELIEF TESTS
48" PIPE LINE
FIRST HIGH SERVICE
In one sheet
Scales as indicated
U.S. Engineer Office, Washington, D.C., April 18, 1934.
Drawn JV.
Checked D.M.R.

Fig. 3.—Charts Illustrating Surge Conditions Before and After Installation of Cone Type Relief Valves on Discharge Lines

supernormal wave reached the station seven seconds after power failure. The results obtained by valve timing were therefore not considered satisfactory because these valves must protect pipe lines of concrete construction which were not designed to withstand the surge pressures encountered.

Further Studies on Surge Relief

Investigations of several methods of surge suppression in pipe lines were then made. It was decided to provide a relief valve on each pipe header in the pumping station. To make the installation it was necessary to provide an outlet from each of the three pump-discharge lines. This was accomplished by installing "Smith" tapping sleeves (Fig. 2) with 10 inch outlets. A 10-inch gate valve was bolted to each sleeve to provide emergency shut-off. The discharge from each surge relief valve was carried into the filtered water reservoir to prevent waste of purified water.

Before deciding upon size of valves to be used, calculations and field tests were made to arrive at the size of relief required. The field tests consisted of a series of surge tests relieved through different sizes of openings. This was done by providing a 12 inch valved opening on one of the pumping station headers. A series of tests was then made under variable pumping conditions with the several orifice plates bolted on the valve. The valve was of the quick opening, hydraulic type, manually controlled. A signal system was installed to insure proper timing of test valve opening. The field tests included surge relief through openings 2, 4, 6, 8, 10 and 12 inches in diameter. It was found that the 2 and 4-inch openings had very little effect in damping the supernormal surge pressure. The 6-inch opening did not damp the first supernormal wave but did damp out the succeeding waves. The 8-inch opening entirely damped or eliminated all supernormal waves. From the results obtained in the field tests it was decided to install 10-inch surge relief valves on each of the pump discharge lines. The chart (Fig. 1) shows the results of the tests made with the orifice plates under variable pumping conditions.

Automatic Cone Relief Valves Installed

The surge suppressor or relief valves installed are of the hydraulically operated, rotary plug type (Fig. 2), manufactured by the Automatic Cone Valve Company, now a division of the Chapman Valve Company. Since the valves meet open when the pressure drops in the pipe lines it was necessary to supply water pressure for valve operating from an independent source of supply. A 60-gallon residential supply water system was installed to insure an unfailing supply of water pressure to the three surge relief valves. The valves operate in the following manner: the normal pressure of the pipe line operates against a spring diaphragm pilot valve which admits control water pressure to the "closing" end of the hydraulic piston.

This holds the surge relief valve in the closed position. When a power failure occurs, the water in the pipe line flows away from the pumping station causing a subnormal wave in the line. This results in low pressure against the control diaphragm, which allows a spring to operate the pilot valve, which in turn allows high pressure control water to flow to the "opening" end of the hydraulic piston which opens the main surge relief valve. The opening action is very rapid, the entire operation requiring only from 1.5 to 2 seconds. The average duration of the first sub-normal wave in the Washington lines is approximately 8 seconds, thus the surge relief valve is wide open before the first super-normal return wave reaches the station. With the surge relief valve open, all succeeding supernormal waves are dissipated through the open valve. The pipe line now assumes a penstock condition and the surge relief valve must be closed very slowly in order to prevent setting up penstock surges. This is done by limiting the flow of control water to the "closing" end of the hydraulic piston. For successful results it was found that a 2-second opening and 2.5-minute closing of the surge relief valves entirely eliminated water-hammer or surges in the respective pipe lines.

Results

During the period of service since these surge relief valves have been in operation in the Dalecarlia Pumping Station several power failures have occurred. High speed pressure charts indicate, however, that pipe line surges have been entirely eliminated as indicated by typical records pictured in Fig. 3.

ANDERSON VALVE CORPORATION

Oliver Building
PITTSBURGH, PA.

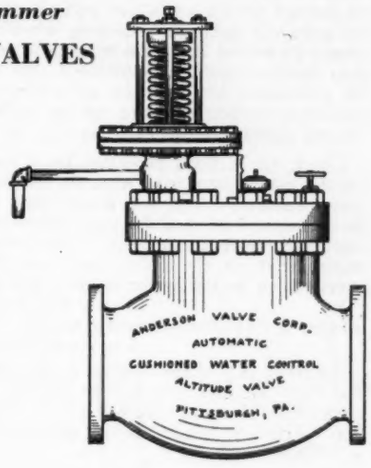
Anderson Automatic Valves for Water Control

Anderson Cushioned Valves Prevent Water Hammer

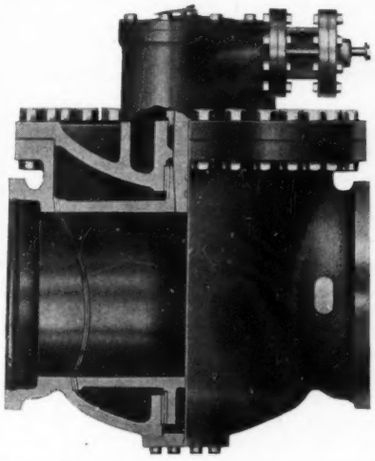
AUTOMATIC CUSHIONED ALTITUDE VALVES

Service: For automatic fluid level control in tanks, standpipes, reservoirs or other containers where separate inlet and outlet pipes are used. Valve shown at the left exhausts to atmosphere. Valve illustrated at right is adapted for installations where ordinary exhaust to atmosphere is not permitted.

Cushioned: In the opening operation by water and in the closing operation by air. Prevents water hammer, shock or jar on high or surging pressures.

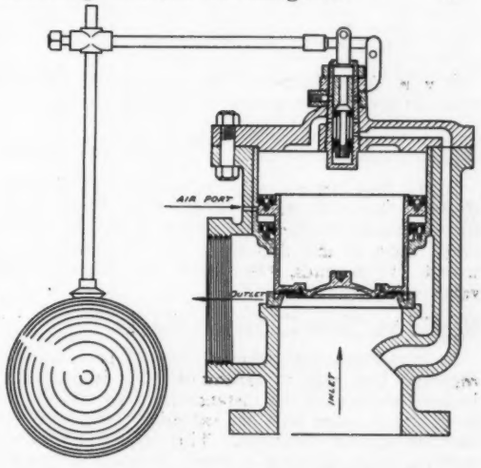


MANUAL OR HYDRAULIC CONE VALVES



Anderson Manual or Hydraulic Cone Valves offer the usual cone valve advantages such as: drop tight in either open or closed positions, reduction of water hammer, negligible loss of head, installation requiring small head room, minimum operating time, seat protection in either position, seat cleaning action, flexible unit construction, sturdy construction with large factor of safety in material and also provide the following inherent advantages:

1. Superior Mechanical Leverage Advantage
2. Automatic Adjustment for Wear
3. Simplified Design
4. Balanced Plug Construction



AUTOMATIC PRESSURE REDUCING VALVES

Service: For maintaining a constant delivery pressure in distributing mains regardless of change in volume requirements. For high or low pressure.

Cushioned: In the opening operation by water and in the closing operation by air. Prevents water hammer.

Valves may be furnished with various controls to meet individual conditions.

AUTOMATIC CUSHIONED WATER FLOAT VALVES

Service: For automatically maintaining any uniform water level in tank, standpipe, reservoir or other containers. For high or low pressure.

Cushioned: In the opening operation by water and in the closing operation by air. Smooth operation prevents water hammer or other shock. Copper float, valve fully bronze mounted throughout.

THE ELIMINATION OF CHECK VALVE SLAM

By H. K. PALMER*
Los Angeles, Cal.

The slamming of check valves when pumps are stopped constitute a source of annoyance and often of expense to water works or sewage works, and allied institutions. Many check valves have an annoying habit of slamming when it is least expected, while others placed on long lines may close quietly. Too sudden closing may easily cause a rupture in a pipe line, a feature which may be eliminated by inclusion of a large air chamber which will eliminate sudden pressure on the pipe but may cause such an abrupt closing of the valve as to crack the flap.

Check valve slam produced by a surge in the water column causes water hammer, with its consequent damage. When a pump suddenly stops, the water tends to continue in motion due to its momentum, and the gage pressure drops to zero. The force tending to stop the motion of the water is proportional to the static head on the pump and such force produces a negative acceleration in the water column according to the formula:

$$F = Ma$$

where: F = Force producing acceleration; M = Mass of water; a = Acceleration.

Letting: A = Area of pipe, square feet; L = Length of pipe in feet; g = Acceleration due to gravity (32.2); w = Weight of a cubic foot of water (62.4 lbs.); h = Static head on the pump; Hf = Friction head; H = Total head; t = Time in seconds; v = Velocity in pipe:

One may: compute the force producing acceleration as being

$$F = h\,A\,w$$

And, the mass of water is found to be

$$M = \frac{A\,L\,w}{g}$$

Then:

$$h\,A\,W = \frac{A\,L\,w}{g}\,a$$

Or

$$a = \frac{h}{L}\,g \qquad \text{(See Figue 1)}$$

If v is the velocity in the pipe before the pump stops, the time (in seconds) required to bring the water to a stop will be

$$t = \frac{v}{a}$$

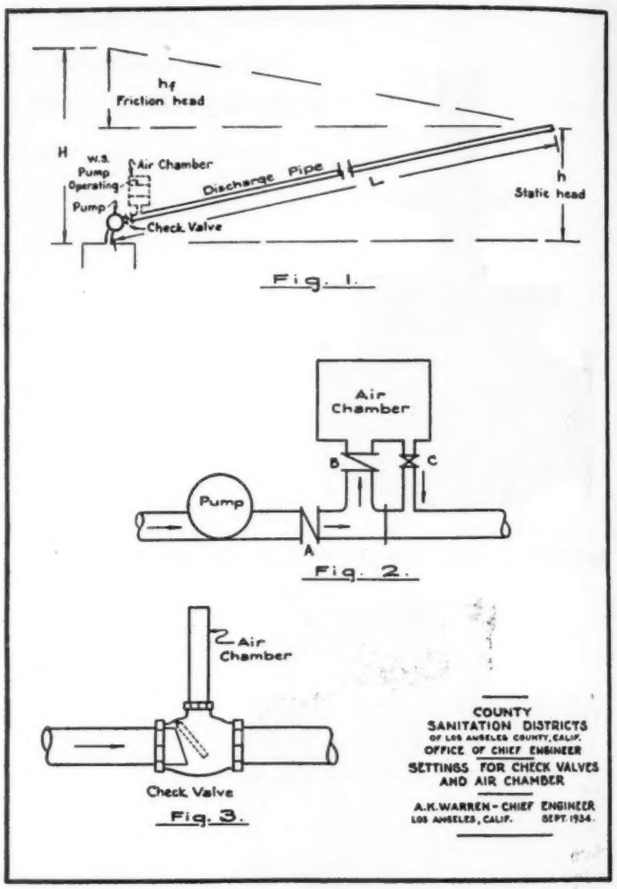
If the flap can come to its seat in (t) seconds or less, it is obvious that the water cannot move backwards and as the flap is moving against the stream it will be cushioned. On the other hand if the flap does not have time to become seated within (t) seconds, the water will start backwards and the valve will close with a slam.

Rapid vs. Slow Closing Checks

It is obvious that what is desired is *a valve that will close rapidly*. One way to accomplish this is to have the valve seat inclined to shorten the distance the flap must move, and another is to use a valve with an extended hinge pin and arm so that the flap can be weighted. This weight prevents the flap from opening fully, causing a small increase in pressure, but accelerates its return movement when the pump stops. On one test in which a four-inch pump was forcing water into a pneumatic tank under 65 pounds pressure, the slam was eliminated by hanging enough weight on the check hinge pin arm to increase the pumping pressure less than one-half pound. This represented one of the most difficult situations for slam elimination because the pump line was short and there was little mass to the flowing water; thus in one controlling formula $a = \frac{F}{M}$, (a) was relatively large: and in the other formula $t = \frac{v}{a}$, (t) was relatively small.

Where it is not practicable to close the check valve in less than time (t), the use of *a slow closing valve* should be considered, but such valves are expensive and must be so designed that the final closure is made very slowly. An air chamber will provide a cushion in case the valve does not close before the flowing water comes to rest and will protect the pipe against excessive pressure. Immediately after the pump stops, the value of the shock absorbing compressed air in such chamber is its cushioning effect, which tends to maintain the gage pressure on the line instead of allowing it to drop to zero. It will thus delay the stopping of the water in the main pipe but the pressure being maintained close to the pump, where the air chamber will normally be placed, produces excessive acceleration in the short length of pipe between the chamber and pump and although the valve will slam violently, the pressure on this section of the pipe will not be excessive. After the valve has slammed the water in the main pipe will slowly come to rest, and then back into the air chamber, the gage showing an oscillation about the static elevation, as a center, with maximum and minimum at approximately $(h + H_f)$ and $(h - H_f)$.

The air cushion in Fig. 1 has purposely been drawn much larger than is recommended in order to illustrate the conditions. If, instead, it consists of a piece of pipe of the same diameter as the discharge pipe and about two or three diameters in height it will not supply enough water to permit any to flow backward through the check valve, thus avoiding a slam and at the same time preventing excessive pipe pressure. A surge will be set up with a maximum pressure of $(H = 2h)$ and minimum $(H = o)$.



Arrangements of Air Chamber Installation to Eliminate Check Valve Slam and Water Hammer

*Chief Draftsman, Los Angeles County Sanitation Districts.

A Successful Arrangement

An air chamber arrangement which has been found to work very successfully is shown in Fig. 2. "A" is the main line check valve, "B" a check valve into the air chamber which should be nearly as large as "A" and set to allow water to enter the chamber. "C" is a gate valve or a plug cock smaller than "B". "C" must be opened or closed by trial until it limits the flow of water from the air chamber enough to prevent slamming of valve "A," and thereafter left in that position. The limited supply to the pipe damps out the surge, yet check valve "B" is large enough to admit a full stream to the air chamber and thus prevent excess pressure on the return flow.

To correct slam in an existing check valve, an air chamber can be built into the cover plate of the valve (Fig. 3). Care must be taken to so adjust the size of such a chamber that sufficient water is returned to close the flap by the time the water comes to rest but not sufficient to produce a slam.

This investigation was made about five years ago by the writer for the Los Angeles County Sanitation Districts and the data obtained applied to the correction of a number of troublesome conditions where valve slam was a problem.

The writer is indebted to E. A. Rutledge of the Rensselaer Valve Company for testing the formulae on many successful water works installations. A. K. Warren is Chief Engineer and General Manager of the Sanitation Districts and A. M. Rawn is Assistant Chief Engineer.

CHECKING WATER HAMMER*

When the water flowing through a pipe is stopped very suddenly there is rise in pressure in the pipe line that may at times amount, roughly, to 50 times the velocity in feet per second at which the water is moving at the instant.

The best cure for water hammer is a slow-closing valve. The next best cure is to provide an air chamber located as close as possible to the valve. If kept fully charged, an air chamber is considered to be of sufficient size when its capacity is one per cent of the pipe line it serve to cushion. Means of renewing the air cushion must be provided for.

Required Volume of Air Chamber

The size, that is, the volume, of an air chamber depends upon a number of factors of which the principal ones are:

The length and size of pipe that the air chamber serves.

The rate of flow of water through this pipe.

The pressure in the air chamber immediately preceding the stopping of the flow, and the pressure due to the stopping of the flow, and,

The nature of the action that puts the air chamber into service—whether it be instantaneous, or rapid, or prolonged.

The following treatment is based upon the first three factors. With reference to the fourth factor—it is the more or less instantaneous stopping of the flow that makes necessary the use of an air chamber. Hence, we are virtually assuming the condition of rapid closing. By this method a volume of air chamber is determined such that the energy of the moving water is absorbed between prescribed limits of pressure in the air chamber.

We have the expression,

$V = L \times P \times R^2$, in which

V is the internal volume of the air chamber in cubic inches,

L is the value from Table 59 for the size and length of pipe that the air chamber serves,

P is the value from Table 60 for the flowing pressure and the assumed maximum pressure, both in the air chamber, and

R^2 is the square of the rate of flow through the pipe in gallons per minute immediately before the stopping of flow.

Note—The flowing pressure can be determined approximately by deducting from the static pressure at the air chamber the loss of pressure in the run of piping (for which the size of an air chamber is being found) under the assumed rate of flow.

Determine the size of an air chamber for a ¾-inch branch, 20 feet long, carrying 10 gallons per minute, based on pressures of 20 pounds per square inch flowing, and 60 pounds per square inch maximum.

Substituting,

$V = 0.042 \times 1.6 \times 10^2 = 6.7$ cubic inches.

Having determined the volume of the air chamber, it becomes necessary to fix the proportions—whether to make it of relatively small diameter and correspondingly long, or short and "dumpy." If made of ¾-inch pipe, length would be 6.7/0.53, or 12.6 inches. Sectional area of ¾-inch pipe is 0.53 square inch from Table 61.

*From "Water Supply in Buildings," by Alex. W. Moseley, Mass. Inst. of Technology, 1935.

TABLE 59
Values of L

Length of Run, Feet	Size of Pipe, Iron Pipe Size ½	¾	1	1¼	1½	2	2½	3	4
10.....	.037	.021	.013	.0074	.0055	.0033	.0023	.0015	.0009
20.....	.074	.042	.026	.015	.011	.0066	.0045	.0030	.0017
30.....	.111	.063	.039	.022	.016	.010	.0068	.0045	.0026
40.....	.148	.084	.052	.030	.022	.013	.0091	.0060	.0035
50.....	.185	.105	.065	.037	.027	.017	.011	.0075	.0044
60.....	.222	.126	.078	.044	.033	.020	.014	.0090	.0052
80.....	.296	.168	.104	.059	.044	.026	.018	.012	.0070
100.....	.370	.210	.130	.074	.055	.033	.023	.015	.0087
125.....	.462	.262	.162	.093	.068	.041	.028	.019	.011
150.....	.555	.315	.195	.111	.082	.050	.034	.023	.013
200.....	.740	.420	.260	.148	.109	.066	.045	.030	.017
250.....	.924	.524	.324	.185	.136	.082	.057	.037	.023

Note that for each size of pipe value of L is proportional to length of run.

TABLE 60
Values of P

Maximum Pressure, Lb. Sq. In.	Flowing Pressure, Lb. Sq. In. 15	20	25	30	35	40	50	60	80	100
20..	42.									
25..	12.	56.								
30..	6.0	16.	72.							
35..	3.8	7.8	20.	90.						
40..	2.6	4.8	9.8	25.	110.					
50..	1.6	2.5	4.2	7.3	14.	36.				
60..	1.1	1.6	2.5	3.8	6.0	10.	49.			
80..	0.67	0.92	1.3	1.7	2.4	3.3	6.9	18.		
100..	0.48	0.63	0.82	1.1	1.4	1.8	3.0	5.4	27.	
120..	0.37	0.47	0.60	0.75	0.93	1.2	1.8	2.8	8.0	39.

TABLE 61
Sectional Area of Pipe

Size of Pipe Iron Pipe Size	Area of Internal Cross-Section of Pipe Sq. In.
½	0.30
¾	0.53
1	0.86
1¼	1.50
1½	2.04
2	3.36
2½	4.78
3	7.39
4	12.7

(The above article should be useful in meter shop practice and otherwise, where quick closing valves must be employed.—*Ed.*)

PRACTICAL ELECTRICITY IN THE PLANT

The A. B. C.'s of Electricity for the Water and Sewage Works Man

By MARSDEN C. SMITH

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Taken from a series of short articles by Mr. Smith, dealing with the A.B.C.'s of practical electricity for water works and sewage plant operators.

The author, a graduate electrical engineer, is a well known water works operator. He is, thereby, peculiarly well qualified to present these discussions, which should be of considerable benefit to operators and designers less thoroughly grounded in electrical matters.

If there are points in his contributions not clear to the reader, Mr. Smith offers to answer inquiries.

THE increasing use of electricity in water and sewage treatment plants produces problems of design, operation and maintenance with which the engineer in charge is generally but little familiar. Fortunately, while advanced electrical engineering is a very involved subject, a helpful and useful knowledge of its fundamental principles can be obtained quite readily by the trained personnel of such plant. To that limited end the presentation of this series of articles is confined.

PART I—ELECTRICAL UNITS

The Volt

One of the most important units of electricity is the Volt. It is the unit of electrical *pressure*. Just as we measure water force or pressure in units of pounds per square inch or feet of head, the unit of electromotive (electric moving) force is the volt. In equations, its symbol is E. Voltage is sometimes expressed in print as the emf—abbreviation for electric-motive force.

Standard voltages are 110, 220, 440, 2,200, 4,000, and 13,200. The individual for whom these articles are intended is rarely concerned with voltages in excess of 2,200. Furthermore, the 110 volt standard is now in the process of change, and seems to be quite generally replaced by a standard of 120 volts.

Extra-heavy fittings and greater precautions are necessary with greater water pressures; so too, must greater care be taken both of life and property when higher electrical pressures are used. However, pressures of as little as 110 volts, in common domestic use, may prove fatal and care should always be taken to avoid personal contact with even these relatively low pressure circuits.

Most electrical apparatus is designed to operate at one of the above mentioned standard voltages. The use of other than these standards is both unnecessary and uneconomical. Incandescent lamps are generally rated at from 110 to 125 volts in five-volt increments. They may be obtained designed for 220 volts, but such lamps are not recommended except where no 110-volt service is available. Even then safety and economy demand the use of 110-volt lamps if possible.

Some Practical Considerations

Lamps are very sensitive to voltage change; and the operator should see that the lamps are purchased for the circuits on which they are to be used. For example, if the average voltage at the station is known to be 118 volts, 120-volt lamps should be used. Here the use of 110-volt lamps would increase the lamp replacement cost by almost 300 per cent.

Motors are not nearly so sensitive to voltage change as are lamps and will operate successfully at applied voltages within 10 per cent above or below normal rated voltage. Greater voltage variation will generally cause excessive heating and unsuccessful operation.

Small motors (less than 5 horse-power) are usually single phase and operate at standard lamp voltages. Large motors, 5 to 50 H.P., are cheaper when designed for 220 or 440 volts. Larger than 50 H.P. should be designed for 2,200 volts. Of course, local conditions may change these recommendations. One large plant has motors from 3 to 300 H.P. The station designers used 2,200 to 440-volt transformers; motors between 50 to 300 H.P. were ordered for 440 volts. A second set of transformers reduced the 440 volts to 220 volts for the smaller motors (up to 50 H.P.). Certainly this is unfortunate, because the larger and more expensive motors would have been of less first cost if designed for 2,200 volts, and the 2 to 5 per cent transformer losses, which materially increases operating costs, would have been saved. The smaller motors could all have been 440-volt type, thus here again would have been saved the second transformer losses. Here we see an evident error that a better understanding of the problem of electricity in design would have avoided.

Other than electrical engineers often fear the use of 2,200 volts. It is true, that there is no need for this higher potential, unless the size and number of motors justifies its use. However, where the total of as much as two or three hundred horse-power is required for motors larger than 50 H.P., the higher potentials are certainly advisable.

The relative advantage of the use of 220 or 440 volts as the operating voltage for the smaller motors is not so definite. However, for larger plants 440 volts seems more desirable. Safety requires the same care with 220 volts as with 440 volts, and a much wider range of motor sizes can be more economically operated at this than at 220 volts.

The Ampere

The second important unit of electricity to be considered is the Ampere.

It is the unit of electrical *rate of flow*. We are familiar with the various measures of the rate of flow of liquids; gallons per minute, etc.; so we should think of the unit rate of flow of electricity as the ampere. In equations its symbol is generally (I). In print Amperes are sometimes abbreviated to "Amp." Larger pipes are required to carry larger rates of flow of water economically; so too, larger wires are needed to carry larger currents (amperes) economically. Small pipes may be uneconomical because friction causes too great loss of water pressure. In exactly the same way, wires may be too small for the amperage (current flow) and cause an uneconomical loss of electrical pressure (voltage drop).

There are no standard currents as in the case for the voltage rating of electrical apparatus. Each appliance, lamps, heating devices, etc., takes from the circuit a current dependent upon its design and lack of resistance to flow. Motors require, for example, a current that varies with the load. All electrical apparatus (except lamps) should have its normal current rating stamped upon its nameplate. Lamp current is determined by dividing its watt rating by its rated voltage.

However, there are certain appliances such as wire, fuses and switches that are rated in terms of the current they may safely carry; thus currents are to this extent standardized. The plant manager should realize that these current ratings are fixed by the National Electric Code, and he should not permit greater current to flow through accessories than the limits established by this code. Oftentimes circuits are fused far beyond the rated capacity of the wire, which is supposedly being protected by the fuse. Such practice is both uneconomical and dangerous.

Most appliances, including motors, are connected between the supply lines, that is, in parallel. In this way the circuit voltage is impressed upon each appliance, causing a current to flow through the appliance of a quantity dependent upon its rating and load. These increments of current are added, hence the supply wires carry greater and greater total current as we work back toward the source of power. For example: Five 1,000-watt

lamps rated 100 volts each require 10 amperes. Let us designate these as numbers one to five, from that nearest the supply to the most remote. Both wires between the supply and the first (No. 1) lamp carry 50 amperes; between 1 and 2, 40 amperes, and so on until between 4 and 5 the current has reduced to 10 amperes, or that required by No. 5—the last lamp. They all have (practically) the same voltages as the supply applied to their terminals.

Some Practical Considerations

When installing new apparatus there are two considerations of great importance: (1) Use wire of ample conductor size. (2) Employ insulation having a large factor of safety. For low potential circuits (less than 600 volts) 30 per cent pure rubber insulation will generally prove more economical than the standard code insulation. Particularly is this true in water and sewage treatment plants due to the prevalence of dampness in such locations. For 2,200-volt circuits rubber insulated cable is more easily installed than is varnished cambric cables. Rubber depreciates must more rapidly when subjected to heat and grease or oil than does varnished cambric, but it is less affected by moisture. For this reason, varnished cambric is never used without some form of outer coating, usually lead. Modern synthetic resins and other compounds are rapidly proving their value for use as the outer protective coating, materially lessening the installation difficulties. These coatings are deserving of consideration.

In general, where expert electrical maintenance is not available, the proper thickness of 30 per cent pure-rubber insulation, on conductors of adequate size for the current they will ever have to carry, will certainly well repay the increased investment cost. Where such expert maintenance is available, varnished cambric insulation may prove better for 2,200-volt circuits.

The Ohm

The unit of electrical resistance is the Ohm. In equations its symbol is (R).

If we close the spigot, even though there be water pressure at the valve, no water can flow because the resistance is too great. The same result is obtained when opening an electric switch; the pressure (voltage) still exists but the resistance (ohms) become so great that no current (amperes) can flow. This is an example of localized resistance.

Electrical resistance may be distributed, in fact *is* distributed along the conductor just as is the pipe resistance to water flow proportional to its size, length and condition. Fortunately, in electrical circuits the loss of voltage (pressure) is always directly proportional to the resistance and rate of current flow. Therefore, the loss of power (to be discussed in the next article) is proportional to the resistance and the square of the rate of flow or current.

An electrical device, such as a lamp, does not use or destroy current in the sense that an oil lamp consumes oil, but by its relatively high resistance limits the current that may flow as a result of the impressed electromotive force—voltage. Thus we have the simple but important equation known as Ohm's Law:

$$E = RI \quad \ldots\ldots (1)$$

There are no standards of resistance; however, the established resistance per unit length of electrical conductors and resistance alloys may be found in any electrical engineer's handbook.

Direct vs. Alternating Current

Formula (1) applies to circuits that contain resistance only, or in which the frequency is zero, as in the case of direct current. This term frequency must now be understood. If the polarity between two wires (A and B) of a circuit is not changed, the current flow will always be in one direction in the wires, thus constituting what is termed direct-current—(D.C.). If we alternate wires A and B from one side of the source to the other, once each ½ second, the direction of current flow in A and B will reverse once every ½ second, and will begin to flow in the original or *same* direction in a given conductor once every second. Electrically we would say that there was being produced "An electromotive force (current) having a frequency of one cycle per second." Fundamentally that is the difference between alternating and direct currents. Modern alternating currents closely follow the sine law in their time-potential value; and the standard frequency in this country is now sixty cycles per second.

When direct current is applied to a coil of copper or other wire (having resistance R) wound around iron, if the current and voltage be carefully measured, equation 1 will be found to apply. When an alternating voltage is applied this equation no longer can be used. This is because any magnetic circuit is an inductive circuit, and the effect of an inductance is to divide the alternating current into two components which are at right angles to one another. Hence to obtain the same current through the coil when an alternating voltage is applied, a greater voltage is required than when a direct voltage is used. So for alternating current circuits equation 1 becomes:

$$E = ZI \quad \ldots\ldots (2)$$

in which Z is the impedance of the circuit.

Many devices, such as heating appliances and lamps have little or no inductance; hence may be used on either direct or alternating current circuits of the rated voltage; but inductive devices, such as transformers and motors, cannot be used on direct current circuits unless especially designed for the purpose.

Transformers

The engineer for whom these articles are intended rarely is concerned with the use of transformers; however, a brief discussion of them is advisable. The standard transformer consists of two stationary coils of wire insulated from one another and wound around a common iron core. A special class, the auto-transformer, commonly used for motor starters, has only one winding with connections to some desired turn between the two end turns.

Of the winding in the auto-transformers, the turns connected to the power supply is the primary; the secondary winding is connected to the load. The voltage change between the primary and secondary is in direct ratio to the number of turns used in the two windings; conversely, the current is in the inverse ratio to the number of turns. Hence a transformer may be used to increase voltage as readily as to reduce it—the so-called "step-down." Many deaths have resulted from opening the high voltage switch, assuming the transformer "dead," when in fact the 110-volt side was still energized thus producing normal high voltage in the primary.

Instrument transformers are especially designed to accurately reduce the potential or current, as the case may be, for metering and other purposes. Care should be taken to always connect the secondary terminals of current transformers together with wire (short-circuit them) if the secondary circuit must be disconnected for any purpose while the primary continues to carry current.

It is well to know that transformers, if kept cool enough, can safely carry much greater than rated loads. Cold winter weather and artificial ventilation around the tanks is effective, but hot locations and days are dangerous. Tank temperatures should never exceed 90 degrees C. Contamination of the oil by dirt or even traces of moisture must be avoided. In larger units the oil should be examined monthly by a competent inspector.

The Watt

Another very important unit of electricity is the Watt, which is the unit of electrical power. The more commonly used unit is the Kilowatt, which is one thousand watts. The symbol for the Watt is (W); for the Kilowatt (KW). The mechanical unit of power is horse-power; one horse-power (H.P.) is the equivalent of 746 watts or 0.746 kilowatts. Due to the fact that the efficiency of small motors is approximately 75 per cent, the input in kilowatts is, by coincidence, closely the same as the mechanical output in horse-power.

With direct current, electrical power is the product of the current (I) and the voltage (E). Thus we have:

$$P = EI \quad \ldots\ldots (3)$$

However, substituting for (E) from equation (1), wherein $E = RI$, we have:

$$P = RI^2 \quad \ldots\ldots (4)$$

Or similarly, substituting for (I) where $I = \frac{E}{R}$ in the same equation:

$$P = \frac{E^2}{R} \quad \ldots\ldots (5)$$

Now, it becomes evident that electrical power varies directly with both current and voltage, if resistance is not considered, but as the square of either (E or I) if the resistance is considered.

PART 2

POWER FACTOR; ITS SIGNIFICANCE

With alternating currents equation (3) becomes the more familiar form, and—

$$P = EI \cos \theta \quad \ldots\ldots (6)$$

In this equation the Cos θ is designated as the power-factor. If an alternating current circuit contains resistance only (no capacity or inductance) the angle θ becomes zero; hence, its

cosine, which is the power-factor becomes unity. Electrical installations in water and sewage treatment plants rarely contain sufficient capacity (condenser action) to be of any practical effect, hence we may omit further reference to "capacity" in these articles. Inductance, however, is of great importance, and in practical installations may reduce the power factor as much as 30 per cent.

The actual mathematical value of the power-factor of practical circuits is difficult to compute; however, it is well for the engineer to have some idea as to the values that may be expected. Incandescent lamps and heating devices, since they contain but little inductance, are virtually non-inductive; hence, their power-factor closely approaches unity. Motors and transformers vary through very wide limits. Of course, a transformer being highly inductive when delivering no load, its power-factor is quite near zero; but, at rated load the power-factor becomes quite nearly that of the circuit being supplied by the transformer. Small motors, up to 5 h.p., require power at not more than 60 per cent power-factor; particularly so when operating at light loads. Large induction motors, at full load, now may operate at as high as 94 per cent; and, synchronous motors, more fully discussed in coming articles, may be operated almost as desired.

The objection to low power-factors is that larger currents are required for the same power, thus increasing power losses in the whole electrical system. Furthermore, low power-factors cause much wider voltage variations than do greater loads with higher power-factors. For this reason many power companies offer reduced rates to those consumers whose apparatus constitutes a load having a favorable power-factor. This fact may be of value to many larger operators. It is true, however, that plant operators can exercise but limited control over the power-factor of their stations except through the selection and operation of the motors. This phase of the subject will be later discussed when motors and their characteristics are considered.

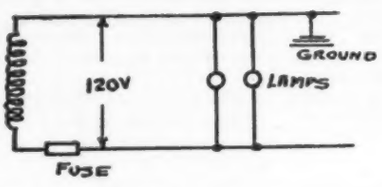


FIG 1

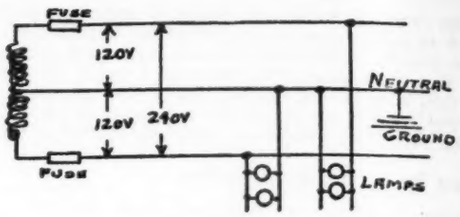


FIG 2

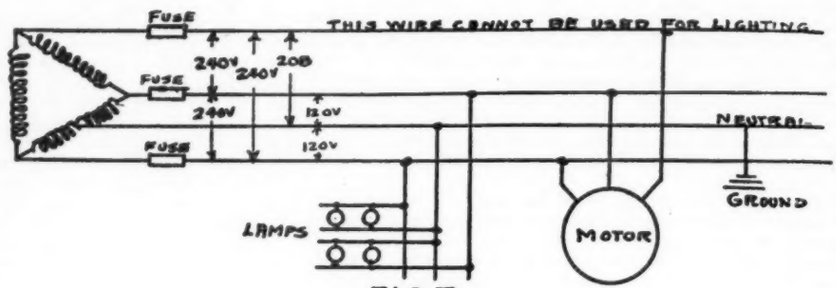


FIG 3

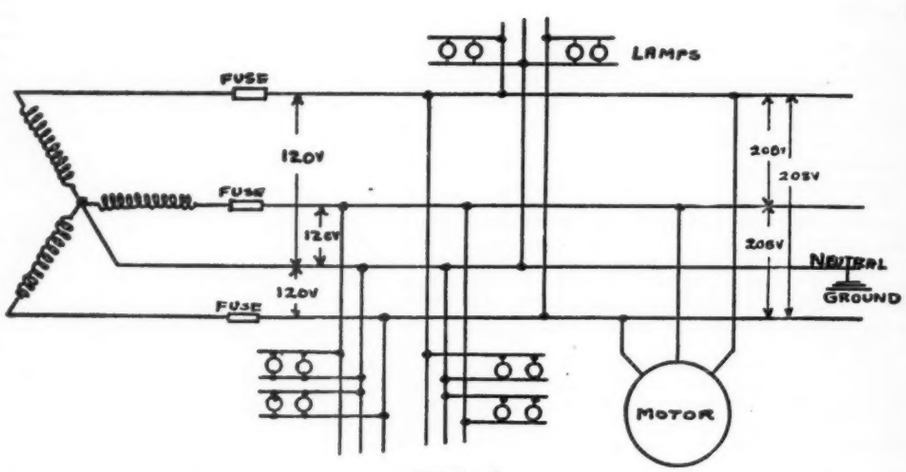


FIG 4

Circuits: *Figs.* 1, 2, 3 *and* 4

The Kilowatt-Hour

The kilowatt-hour (KwHr) is the unit by which electric power is generally sold. As its name implies, it is the average power consumed, in kilowatts, multiplied by the number of hours involved. For example: if an electric iron is operated for two hours at average rating of 600 watts, there is used $600 \times 2 = 1200$ watt-hours, or 1.2 KwHrs.

The volt-ampere (VA) is the product of the volts and amperes of a circuit or an appliance, without reference to power. Thus, the transformer is always rated in kilo-volt-amperes (KVA) because its parts can be designed for the voltage and current value desired, but the power-factor of its load may vary through wide limits. Thus we see that:

$$KW = KVA \times \text{Cos } \theta \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Hence, if we are to know the safe load for a transformer rated at 100 KVA, we must first determine the power-factor of the load to be connected. If we may assume the load to be one-half lamps and one-half small motors; we may approximate the average power-factor to be 82 per cent. Hence, by equation (7) we find $Kw = 100 \times 0.82$ (82 Kw) to be the safe load for this case.

The Cos θ, which we now recognize to be the power-factor, is actually the cosine of the angle of time-phase displacement between the current and the voltage of an alternating current circuit containing "capacity" or inductance.

Circuits

The term, "phase," is also applied to designate the circuits of an alternating current system. In the "Single-Phase" system the *voltages* are in the same time-phase in all parts of the system. In the "Two-Phase" system, the two voltages are 90 degrees apart. In the "Three-Phase" system they are 120 degrees apart.

In another sense, there are in effect one or two or three circuits in the single, the two or the three-phase systems. Of course, the power-factor may be different in each phase; hence the currents in the phases may not be of exactly the same angular difference as the voltages producing these currents.

The simplest circuit is that comprising the single-phase (two-wire) system, as in Fig. 1. This is used for the final branch circuit of larger systems, and in case of small loads, including most residences, it is always used.

The single-phase, three-wire system is next in capacity and in frequency of use. Single-phase, two-wire branches are connected thereto as shown in Fig. 2. The evident advantage of three wires over the two-wire system is that when loads are

balanced, the neutral carries no return current, hence the lamps and appliances operate at 120 volts, whereas the circuit operates at 240 volts. In this way twice as much power can be carried over the same wires, by merely adding one additional wire.

Grounding Practice

The neutral must be grounded. It should be the same size as the phase wires; and, it must *not* be fused or connected to any switch, and the wire used for the neutral must have white covering for identification, and the neutral must be connected to the white screw in all receptacles. In the single-phase, two-wire system one of the wires must be grounded and the same rules as given for the neutral conductor wire must be observed.

(Grounding practice as it affects water works piping will be given some discussion at a later point in this article.)

Three-Phase Standard for Heavy Duty

The three-phase (three-wire) system is standard for motor loads. If lighting is required, the neutral of one transformer (made larger to carry the additional load) is brought out as in Fig. 3. Most power companies limit the single-phase load that may thus be supplied to 50 KVA. In addition, this method of supplying the lighting loads makes service interruptions more frequent because of the necessity for grounding one of the transformer windings. Perhaps most serious of all is the objectionable flicker in the lights obtained when starting motors, particularly elevators connected to the system. Of course, economy often rules and hence this system is frequently used; but unless the motors are relatively small, and are started very infrequently; it is undoubtedly better to separate the lighting and very small motors from the power system.

The formula for power in the different systems, with balanced load, is given in the following table:

System	*Power*		*Max. Volts to Ground*
Single-Phase (Two-Wire)	$P = EI\cos\theta$	Here E=120	120
Single-Phase (Three-Wire)	$P = EI\cos\theta$	Here E=240	120
Two-Phase (Four-Wire)	$P = 2EI\cos\theta$	Here E=120	120
Three-Phase (Delta)	$P = \sqrt{3}EI\cos\theta$	Here E=240	207.8*
Three-Phase (Y)	$P = \sqrt{3}EI\cos\theta$	Here E=207.8	120

*Volts to ground on lighting circuits is 120.

The two-phase (four-wire) system is so little used that no discussion is necessary.

PART 3—CIRCUIT PROTECTION

Fuses and all electrical circuit-breakers are similar in function to the safety valve on a boiler; and hence they should be seriously considered. They are all intended to open the circuit, thus stopping the flow of current, should the current exceed a predetermined or dangerous rate through these safety devices.

While the problem of circuit protection becomes at times quite involved, still there is much that can here be discussed to advantage. In the first place, the Natinal Electric Code is now almost universally accepted as the authority for the safe utilization of electricity in all except central station systems. Consequently, the engineer should obtain a copy of this useful and important publication.

Fuses and Circuit Breakers

Fuses are the cheapest and simplest of all protective devices. They consist of a piece of relatively high resistance alloy wire or tape, designed to melt, and thereby part, at the current at which the fuse is rated. The wire is enclosed in a suitable flame-proof case to prevent ignition of surrounding materials at the time the fuse flashes and melts. The use of fuses is now confined almost entirely to circuits the importance of which does not justify the more expensive and accurate devices. The type now approved, known as the "refillable type," permits the renewal of the fuse link, using the expensive part (the cartridge) over and over again.

For those applications in which the replacement of fuses is frequently necessary, thermal relays or air circuit breakers are to be recommended. Motor circuits fall in this classification. Thermal relays and circuit breakers can permit a greater than rated current pass for a short time, as during the starting period of a motor, and therefore are of especial advantage for this service. The current capacity as well as the voltage ratings of this class of protective devices are limited, and when greater limits are needed the oil circuit breaker must be used.

The oil used in circuit breakers must be especially selected for this service; and no other oil should ever be used. This precaution is essential for the reason that the oil must have high insulation value, high flash point, low carbon content, and wide temperature viscosity constant—all in order to quickly quench the arc that is formed with each opening of the contacts.

Relays

The overload operation of an oil circuit breaker is usually actuated by an auxiliary device known as a relay. Relays may be of several types: the instantaneous, the inverse time limit, and others. The modern relays are truly marvelous devices; however, the types needed by the water works plants are, in the main:

(1) *The Instantaneous Type*—dash-potted relays with direct mechanical trip. Here a coil which carries all or a definite part of the load current raises a solenoid when the current flow exceeds a predetermined value. The rising solenoid mechanically releases a trigger, which in turn permits the oil circuit breaker to open. An oil-filled dash-pot retards the solenoid movement. The dash-pot opening is adjustable, hence the time for opening with a given over-current can be selected as desired. The oil in the dash-pot should be inspected at intervals and replaced if dirt or sludge has accumulated. While rather crude, this device is sufficiently accurate for the protection of most small motor circuits.

(2) *The Air Bellows Type*—This type is not much used now. An air bellows, with an adjustable escape valve, is substituted for the oil dash-pot described above.

(3) *The Induction Type*—This relay is more expensive than those above mentioned, but its use is justified in the protection of all important cicuits.

With the induction relay, when the current exceeds the desired value, the torque on an aluminum disc, mounted on the same shaft with the relay contacts, causing the shaft to rotate. Such rotation causes the opening (some cases the closing) of the relay contacts, which in turn electrically energize the main tripping coil on the circuit breaker. The advantage of this type is that the time of opening the main circuit breaker can be determined to a fraction of a second; also, that the limits of control are so wide that these relays, with suitable current transformers, become almost universally applicable and highly accurate protective devices.

To repeat, too much care cannot be given the subject of circuit protection. Over-fusing (use of fuses with too great capacity) of circuits is dangerous and uneconomical. Noting a too frequent operation of the overload, protection of any appliance warrants prompt investigation. The source of the trouble should be remedied by correction, rather than following the easiest path of using too large circuit protection to overcome an annoying operating circumstance.

Grounding—Its Essentiality

It is no exaggeration to say that without adequate grounding, satisfactory electrical service would be virtually unknown. In addition, safety would be a word more than a reality. Even so, many groundings are so deficient in quality as to become actually a hazard instead of a safety effect. Many persons have been swindled into paying for a false sense of security when installing lightning rods having many ornamental glass balls but no grounds. Thereby the victim is actually inviting the lightning to strike the house but offering no protection by way of a cable or rod to conduct the electric discharge into the earth and there dissipate it.

Grounds should be carefully made. Use not less than No. 2 B&S gauge copper wire. Several grounds are preferable to a single ground in order to lessen the chances of broken connections. Use the water pipe system; the larger the pipe, the better. Do not use the gas, gasoline or oil pipe lines. Be sure the connection between the wire and pipe is electrically and mechanically as perfect as possible. If no pipe system is available, drive at least three 1¼-inch pipe, or equivalent copper rods, *well below the moisture line* in the earth. A good test is that the driven ground connection, when shorted, should blow a 30-ampere fuse at 120 volts.

Much discussion has recently been raised in the water works field as to the effects of attaching the electric circuit "neutral" wires to the water pipes. There is no question that the damage done to water systems by stray direct currents, as from street railways, has been indeed enormous. Here we have electrolysis at its worst, and the destruction of the metallic pipes at spots where the current leaves the pipes is rapid. This condition is inexcusable and should be prohibited everywhere.

However, in the alternating current system the damage is not so evident, and many doubt its *real* existence—or at least its seriousness. Also it is quite possible that were all connections between electrical and water systems removed, electrical service as we know it today would be a thing of the past. And even should such action force the electric companies to seek other means of obtaining the necessary protection now provided by these ground-

ing attachments, the water systems would be subject to the same distress now *debatedly* suffered. It would seem certain that more severe difficulties would be caused by the same currents finding their way to the water system in a then uncontrolled routing and dissipation which present practices have been designed to effect.

The necessity for grounding the electric circuits is to prevent dangerous high-potential voltages (through mistakes or accidental contact) from increasing the normally low-potential circuits to a dangerous loading. The wiring for lighting systems of buildings is designed for a maximum of 150 volts to ground. Let us assume that a street series circuit operating at 5,000 volts should fall across the service wires from the pole to your home. With no ground on the "neutral" of your secondary wiring, its potential would be raised from its normal low value to a maximum of 5,000 volts. Certainly something must happen; either a fire is started, or perhaps a member of your family may be killed. The effect of such danger has been observed when service thawing current reaches the house wiring. In these instances the "ground" has worked in reverse, but proves its safety value and the necessity of "breaking" the service line before electrical thawing is started. Now consider these same conditions to exist, except that now your "neutral" is properly grounded. When the high-potential circuit is now temporarily crossed with service, the high-potential currents are safely carried to ground, and no one in the home would realize the possible disaster that the ground connections have avoided.

When, What and Why Ground?

There is no doubt that a full study and discussion of the entire subject of grounding by the new functioning joint committee will prove well worth while. It is certainly to be hoped that there will result a greater care in the preparation and arrangement of ground connections between the electric and water systems, and that the volume of curent flow be intelligently regulated. We, the water utility interests, should not embarrass this effort by hasty demands to prohibit all grounding of water systems. As a matter of fact, we could not do so, even if thoughtless enough to demand such.

[Water works men have themselves found difficulty in effectively grounding pumping station motor circuits by any other method than an efficient connection to their own pressure mains leaving the station.—Ed.]

No wires used in lighting systems should have more than 150 volts to ground. The wires of power circuits, such as 220 or 440 volts, *should not be grounded.* All appliances, frames of motors, conduit, etc., in addition to the "neutrals" of lighting systems, should be carefully and effectively grounded. Inspect grounds frequently. The snuffing out of a life may be the penalty if you do not. Satisfactory operation is another, if secondary, reason for so doing.

PART 4—MOTORS

Alternating current motors are of two general types: the synchronous and induction. The main difference between these two types is that, while the synchronous motor can run only at a definite constant speed (synchronous speed), the induction motor must operate at a speed dependent upon the load applied, but never at synchronous speed. There are other important differences that, to better advantage, will be mentioned later.

Synchronous Type

At a given frequency the speed of a synchronous motor may be determined by the equation;

$$N = \frac{120f}{P} \quad \ldots\ldots\ldots (8)$$

in which N = revolutions of rotor per minute (RPM); f = frequency in cycles per second; P = number of poles.

Since the standard frequency is 60 cycles per second, equation 8 is generally expressed in the form:

$$N = \frac{7200}{P} \quad \ldots\ldots\ldots (9)$$

From this it is evident that the maximum speed for a 60 cycle motor is 7200/2 or 3600 RPM, and the speed, N, from equations 8 or 9 is known as the synchronous speed of the motor. This, for 60 cycle motors, is the constant 7200 divided by the number of poles; and, since the number of poles must be an even number, synchronous speeds become 3600, 1800, 1200, 900....RPM. One of the greatest limitations of the synchronous motor is that it cannot be built to operate at other than synchronous speeds, when oftentimes an intermediate speed is needed.

On the other hand, the fact that it runs at an exact speed is quite frequently its greatest asset. Electric clocks and timing devices depend upon this characteristic for their value and dependability as to accuracy. Pump drives, and mechanical devices of all types that require an exact and fixed speed, necessitate the use of the synchronous motor for this reason.

Another marked difference between the synchronous and induction motor is that the former requires salient magnetic poles, excited (magnetized) from a source of direct current; whereas, the induction motor has no such poles and requires no separate excitation. In fact, the standard squirrel-cage motor is well named, because its rotor is essentially nothing more than a circle of bars parallel to the shaft which are held in place and short-circuited by two metallic rings. Picture the revolving cage for the squirrel's exercise and you have it—thus, the name.

Unfavorable Characteristics

The necessity for this auxiliary direct current is indeed unfortunate, because direct current generators are difficult to maintain. Hence, greater skill and maintenance are required for synchronous than for induction motor operation. Then, too, the starting characteristics of the synchronous motor are rarely satisfactory. The starting torque (that is, the twist or pull) cannot approach that of the induction motor; frequently necessitating expensive and complicated methods of holding the load off the motor until it has reached full speed. Fortunately, centrifugal pumps may frequently be started under no-load without inconvenience, which renders this deficiency of the synchronous motor of no real importance.

Favorable Characteristics

On the favorable side of the ledger, the synchronous motor does possess the ability to operate with a "leading" power factor, contrasted to the rather decidedly "lagging" power factor of the standard induction motor. As has been stated previously, many power companies offer a lower rate to consumers whose requirements make permissible a desirable power factor. Where this is the case, the ability of the synchronous motor to operate at the "leading" power factor may have influence in the selection of the type of motor to be adopted.

From the above, it can be seen why, for water works and sewage treatment plants, the use of synchronous motors is frequently advised against. They are only to be considered when exact speed is essential or power costs may be lowered appreciably by the favorable power factor. Even then, the engineer will do well to be certain that savings in power bills will offset the increased operating difficulties that are certain to be realized in the use of synchronous motors.

Induction Type

The induction motor differs from the synchronous type in that it requires no separate excitation, and its ability to operate at a variable speed, as contrasted to the constant speed synchronous motor.

At no load an induction motor will run almost up to its synchronous speed. It should be understood that while the induction motor has no salient poles, the stator is wound to produce two, four or any even number of poles, just as is the stator of a synchronous motor; hence it has a synchronous speed of 3600, 1800, 900 RPM, just as does the synchronous type.

As the load on an induction motor is increased, the speed gradually lessens until at full rated load the speed is reduced from two to four per cent of its synchronous speed. Thus a given motor may have a synchronous speed of 1200 RPM, a no load speed of 1199 RPM and a full load speed of only 1170 RPM. If the load is further increased, the "slip" (as the loss of speed is called) will increase until a definite value is reached, at which point the motor will come to a stop. This load is known as the "pull-out" load.

Favorable Characteristics

Standard induction motors have very favorable starting characteristics, requiring relatively a small starting current and producing 200 or more per cent of full load torque. They are the most rugged and reliable of all motors. But while they will successfully operate under most adverse conditions, reasonable care should be taken to keep the air ducts and windings free from lint and dirt. The oil in the bearings must be flushed and changed at least once each year.

Smaller and specially designed induction motors require no starting device, and may be started by applying normal full voltage. Larger motors require reduced voltage for starting, which is

usually obtained from auto-transformers, called starting compensators. Two coils, each on an iron core, are connected open-delta across the three-phase lines; a 40, 50 or 60 per cent tap is taken to the motors for starting. After the motor has started and reached a constant speed, the compensator is disconnected and full voltage goes to the motor.

Variable Speed Motors

The wound-rotor induction motor, for operating at variable speeds, is not so rugged as is the standard squirrel-cage type. It is more expensive and also usually less efficient. A misunderstanding of the speed characteristics of these motors has caused no end of trouble. We may gain a clear conception of the speed variation of the wound rotor, induction type motor if we think in terms of "slip." As stated above, the standard squirrel-cage motor "slip" varies from virtually nothing at no load to about 3 per cent at full load. With the wound rotor, external resistance may be added to the rotor circuit, the effort of which is to *increase* the slip. Hence, this motor will run at essentially *constant* speed at no load, regardless of the amount of external resistance introduced in the rotor circuit. But, as the load is applied, and the greater is the external resistance, the more rapidly will the speed drop off.

Practically, this means that if we desire to drive a centrifugal pump at a variable speed, in order to vary the head and quantity delivered, we must first learn from the pump manufacturer both the speed and the horse-power required by the pump for each value of head-quantity desired. This data is then furnished the manufacturer of the motor who will design the external rotor resistances so that the various controller positions will connect the correct resistance to cause the speed to be that needed for the pump to operate under the desired condition.

Since power is a product of speed and torque, it should be remembered that less horse-power output can be obtained from a motor operating at a reduced speed than at its normal full speed. The reduction in motor output is approximately proportional to the reduction in speed. This fact should be considered at the time of purchase in order to be certain that the motor will not be excessively heated when operating at any of the reduced speeds. The same resistors that serve for speed control are also used for starting, hence no compensator is required as is the case for some of the standard squirrel-cage types.

Motor Ratings

The rating of most electrical apparatus such as motors, transformers, etc., is based upon the temperature rise that will occur when the device is operated continuously under normal full load and normal voltage conditions. Many manufacturers recommend a limit of fifty-five degrees centigrade rise, while other base their estimates upon a rise of only forty degrees. After all, this simply means that with a given motor rated at 100 HP, at 40 degree rise would be rated at 125 HP at 55 degree rise. All things considered, it seems to be the consensus of opinion, and dictate of wisdom, that all important motors in water works and sewage treatment plants should be purchased for a guaranteed rise, not to exceed forty degrees centigrade.

RAPID EMERGENCY METHOD OF THAWING HYDRANTS

By E. E. JACOBSON

Chief Engineer, Lexington Water Co., Lexington, Ky.

One of the many worries of the water works man during the cold winter months is the problem of fire hydrant maintenance and their operation when the thermometer drops below freezing.

Proper inspection and drainage of fire hydrants will eliminate most of the trouble but hydrants only a few days after inspection have been found to contain water in the barrel. As the weather turns cold the water in the barrel becomes ice and the hydrant will not operate. No doubt every water works superintendent in states that have cold winters has experienced frozen fire hydrants.

The method used in Lexington, Ky., for a number of years as an emergency method of thawing ice from hydrant barrels is by pouring concentrated sulphuric acid into the hydrant barrel. During the Fall each piece of apparatus of the Lexington Fire Department is supplied with a quart bottle of sulphuric acid (66% commercial). When the acid is used the Lexington Water Company is notified and another bottle is sent to the fire station. In the Spring of the year these bottles are collected and fresh acid is issued each Fall.

When answering an alarm and a hydrant is found to be frozen, the acid is poured into the barrel through the nozzle and a slight pressure put on the stem operating wrench. As soon as the heat produced by the acid drills a hole through the ice cake the hydrant is opened, flushing out the acid with the first gush of water.

In frozen hydrants we have found that the ice forms first above the valve and in most cases it is doubtful if the acid reaches the valve because the stem turns and the water is turned on as soon as the ice melts around the stem.

The average time for thawing hydrants with acid is about three minutes although this would depend upon the thickness of ice in the barrel of the hydrant, and might vary considerably from the above time if very thick.

The advantages from this method of thawing hydrants comprise the ease of handling the thawing material on the fire trucks, the small space necessary on the trucks, simple to use, inexpensive, and the rapidity of results. Hydrants in which acid was used have been taken apart and no ill effects to the hydrant parts could be found.

The effectiveness in the use of sulphuric acid for this purpose can be determined by the following letter from the Chief of the Lexington Fire Department:

Mr. E. E. Jacobson, Chief Engineer
Lexington Water Company,
Lexington, Kentucky.

Dear Mr. Jacobson:

Relative to our conversation this morning, I am furnishing you with all the information that I have in regards to the use of sulphuric acid in thawing fire hydrants during extreme cold weather.

In case a hydrant is found to be frozen, one of the caps of the hydrant is removed and a quart of acid is dumped into the barrel of the hydrant. The suction hose is then replaced on the hydrant, and in the majority of the cases the hydrant is thawed out by the time the suction is replaced, and the hydrant is turned on. The water and acid is allowed to flush out through the pumper or the hose, and we have found that little or no damage is caused by this action, due to the fact that the acid is neutralized by water to such a degree that it is harmless to the pumper or the hose.

In some instances the acid is a little slow about thawing the hydrant, but in these cases it is usually in certain parts of the city, where the surface water seeps in the barrel of the hydrant, causing the hydrant to have more water than usual in the barrel, but as soon as these hydrants are found, your company has had them filled with alcohol, thereby eliminating this trouble.

You will notice that we say that we replace the suction or the hose to the hydrant before we turn on the water. This is done to prevent acid burns to members of the department and the hose and apparatus that is near the hydrant. The first spurt of acid and water from the hydrant would be dangerous to any thing that it touched, but by replacing the cap, the acid is diluted with the water to a point where it is practically harmless to any thing it might touch.

It has required from two to eight minutes to thaw a hydrant with acid, where it usually requires about ten minutes to thaw out a hydrant with a regular thawing device, old style thawing device.

A test was made at fire department headquarters today. A fifty pound block of ice was used and one quart of sulphuric acid was poured into a hole in the ice. Ten minutes later a hole was burned in the ice eight inches deep, six inches wide and ten inches long. Of course, this was a little longer than it would have been in a hydrant, due to the fact that acid will follow the stem of the hydrant and penetrate into the ice faster than it did during the test. We have found the use of sulphuric acid for thawing hydrants to be most satisfactory.

C. J. HENRY,
Chief, Lexington Fire Department.

HILL-HUBBELL and COMPANY

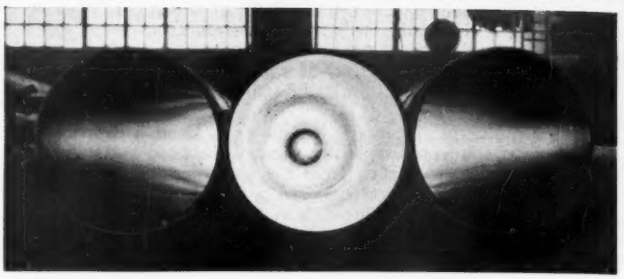
DIVISION OF

GENERAL PAINT CORPORATION

STEEL PIPE PROTECTION for Water Mains and Supply Lines

CLEVELAND, OHIO

The HILL-HUBBELL PROCESS of STEEL PIPE PROTECTION is on a MACHINE APPLIED PRODUCTION BASIS . . . .



BITURINE AKWALINE ASSURES HIGH "C" FACTOR

BITURINE AKWALINE ENAMEL is melted and heated in mechanically agitated and thermostatically controlled bitumen kettles. For lining STEEL PIPE, the duration of heating is kept to a minimum by the rapid application to the inner surface of the horizontally positioned power rolled or spun pipe. The feed line placed at the bottom of the pipe, disperses the flow of hot enamel in quantities sufficient to build up a multiple application thus covering and protecting the inner wall of the pipe with a smooth, resilient surface.

BITURINE ENAMEL COATING and KRAFT PAPER WRAPPING

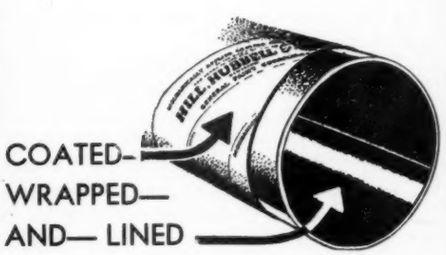
BITURINE AKWALINE PRIMER is the first process in the protection of the pipe surface. Rapidly rotating weighted bristle brushes force the primer into every irregularity of the steel structure. BITURINE AKWALINE COATING—AND—WRAPPING is also machine applied; again minimum duration of heating is attained by exceptionally rapid application—After the second coating is applied there are no skips, holidays or bubbles, the felt wrapper is applied by flooding the inner surface with the hot coating, before it is wound on the pipe under fixed mechanical tension. Another coating is applied before the protective cover of 80 lb. Kraft Paper is spirally wound in place. HILL-HUBBELL AND COMPANY printed on the Kraft paper covering stamps it a product of worthy CRAFTSMANSHIP.

STEEL PIPE HAS MANY OUTSTANDING ADVANTAGES

For many years STEEL PIPE has been used for water mains—It is particularly applicable, because of its shatter-proof strength, flexibility, ductility, long lengths, lower installation costs and greater enduring capacity. With HILL-HUBBELL MODERN methods of pipe protection applied to it, it gives long service at low maintenance cost.

SMALLER THAN 2⅜" O.D. CEMENT LINED STEEL PIPE

A specially designed pipe to replace non-ferrous tubing smaller than 2⅜" O.D. is CEMENT lined steel pipe. It is prepared with the same high quality Coating-and-Wrapping as the larger dimension pipe.



HILL-HUBBELL PIPE PROTECTION MEETS A.W.W.A. 7A.6

COATING — AND — WRAPPING — AND — LINING with BITURINE AKWALINE PRIMER AND ENAMEL complies fully with A.W.W.A. Specifications 7A.6.

DETERMINING THE CONDITION OF MAINS

How to Watch Your "C" Line for Friction Losses

By D. R. TAYLOR
Plant Superintendent, Water Department
Roanoke, Virginia

THERE are men who report to their physicians regularly for physical examinations. These men are not concerned about the surface of their anatomy—they can see that; they want to know the trend of that part of their "human plant" that is under the surface.

Among other things, they want to know the friction loss in their circulatory system, and if an increase of this friction is causing a diminution of capacity and a corresponding dissipation of power. They are anxious to take immediaate and proper remedial action if the friction is building up too fast and capacity is falling.

How Are Your Water Arteries?

Realizing that probably 80% of the worth of your water works "anatomy" is represented by its "arteries," also hidden under the surface, leads to the question—How *old* are your water supply arteries? And I do not mean in years, but in the matter of "oldness" in terms of that all important criterion—friction build up and failing capacity. Only if you are watching your "C" line will you know; otherwise you can only be guessing.

How to Find Out

The "C" Line I refer to is no other than the important line to show the status and trend of the coefficient of friction of pipe lines which you have frequently heard referred to as the "C" value of mains.

Determination of the "C" value derived from the famous Williams & Hazen formula may sound formidable and difficult but it really is not and I hope to be able to convince you of as much by showing how relatively simple it is to secure the needed test readings on a length of main and derive therefrom the "C" value (friction coefficient). In short, how you can answer the question—How old are your "arteries"?

This type of work is not only interesting but is full of surprises. It is the most positive and effective method of determining the necessity for reducing the friction in these important arteries and the need for treatment to prevent corrosion. Then, afterwards, what the results of such treatment are. Likewise, if there are advantages to be gained in the use of lined pipe. Finally, as an added guide in planning future developments and additions. After you have selected and tested sections of representative mains, you will have enough curiosity to make a second test within six months, after which an annual check-up is usually sufficient, depending upon results obtained.

The computations necessary are not as intricate as the average water works operator seems to think they are. You need not worry about being "rusty" in the use of a slide rule and unfamiliar with logarithms. You do not need to have a dizzy spell when you see the formidable looking formulae.

A Simple Method of Finding "C" Values

Herewith is a tabulation of diameters and areas of both pit cast and super deLavaud Cast Iron pipe which is self-explanatory, and, although "slipped off" on a slide rule, is sufficiently accurate for the work. I am also enclosing a data sheet presenting two logarithmic curves, the necessary formulae, conversion factors and explanation of symbols. These are all that I find necessary for ordinary purposes in solving flow problems.

In the upper right hand corner of the graph sheet are the simple formulae for determining quantity, velocity, and areas. Formula (1) in the center of the sheet is the original Williams and Hazen formula for the solution of velocity. It is more simply expressed in formula (2). Formula (3) is that employed in calculating these "C" values. Formula (4) is for the solution of "S," which represents hydraulic slope or friction loss. Formula (5) gives the same value more simply.

Procedure

Suppose that you are testing a section of unlined pit cast main with a nominal diameter of 10 inches. Say it is 800 feet long between pressure gauges, and that the measured rate of flow from the hydrant at the far end was 1036.8 gallons per minute. Let us say that the pressure drop between stations (shown by the difference in readings of the two pressure gauges) was 7.13 lbs./sq. in. This represents the friction loss (S) for the 800 ft. run between these two points.

Now, what is the coefficient of friction ("C" value) of this main?

By reference to the formulae on the data sheet we will find that

$$Q = 1036.8 \text{ g.p.m.}$$

$$Q = \frac{1036.8}{448.83} = 2.31 \text{ c.f.s.}$$

$$V = \frac{Q}{A} \text{ and } A = .5454$$

(10″ pipe table 1.)

$$V = \frac{2.31}{.5454} = 4.225 \text{ ft./sec.}$$

The hydraulic radius of 10″ pipe
$R = .2083$ (from table).

Friction loss (hydraulic slope)
$S = 7.13$ lbs./sq. in. (for 800 feet).

Convert to feet loss
$= 7.13 \times 2.31 = 16.47$ feet.

Per foot of main:

$$S = \frac{16.47}{800} = .0206.$$

Now for the formula:

$$C = \frac{V}{1.318\ R^{0.63}\ S^{0.54}} \text{ in which}$$

$$R^{0.63} = .2083^{0.63}$$

Although shown in the table, this value can be secured from the graph as follows: On the base line, we locate .2083 (R). From this point, move vertically up the sheet to intersect diagonal "B"; thence horizonally to the vertical axis, where we find 0.372. Therefore $.2083^{0.63}$ is 0.372.

In a similar manner, by intersecting diagonal "A," by following up the .0206 (S) line from the base, we find:

$$S^{0.54} = (.0206^{0.54}) = .1225.$$

Therefore; according to the formula,

$$C = \frac{4.225}{1.318 \times .372 \times .1225} = 70.3.$$

In use of formula (5), by employing cure "A" "in reverse," any number raised to the 1.85185th power can be had.

For instance, using the above values in formula (5)

$$S = \left(\frac{4.225}{1.318 \times 70.3 \times .372}\right)^{1.85185} = .1225^{1.85185}$$

Find .1225 on the vertical axis, move horizontally to the right to diagonal "A" and then drop down to the base line, and we find .0206.

Therefore; $S = .0206$.

In order to be as brief as possible this explanation may require a little close study. However, the information should prove sufficient for fairly accurate evaluations.

Let me warn you though to caliper the hydrant nozzle through which the rate of flow is determined. Contrary to the common assumption, this diameter is rarely exactly 2½ inches.

If, after you have pursued this task for a while, your enthusiasm becomes more acute and the magnitude of your study warrants it, you might purchase two calibrated precision altitude gauges to replace your pressure gauges and a K. & E. log-log duplex decitrig slide rule, which is not nearly as difficult to use as you might think. With the use of the log-log scales on this rule, you can accurately and quickly determine the fractional powers

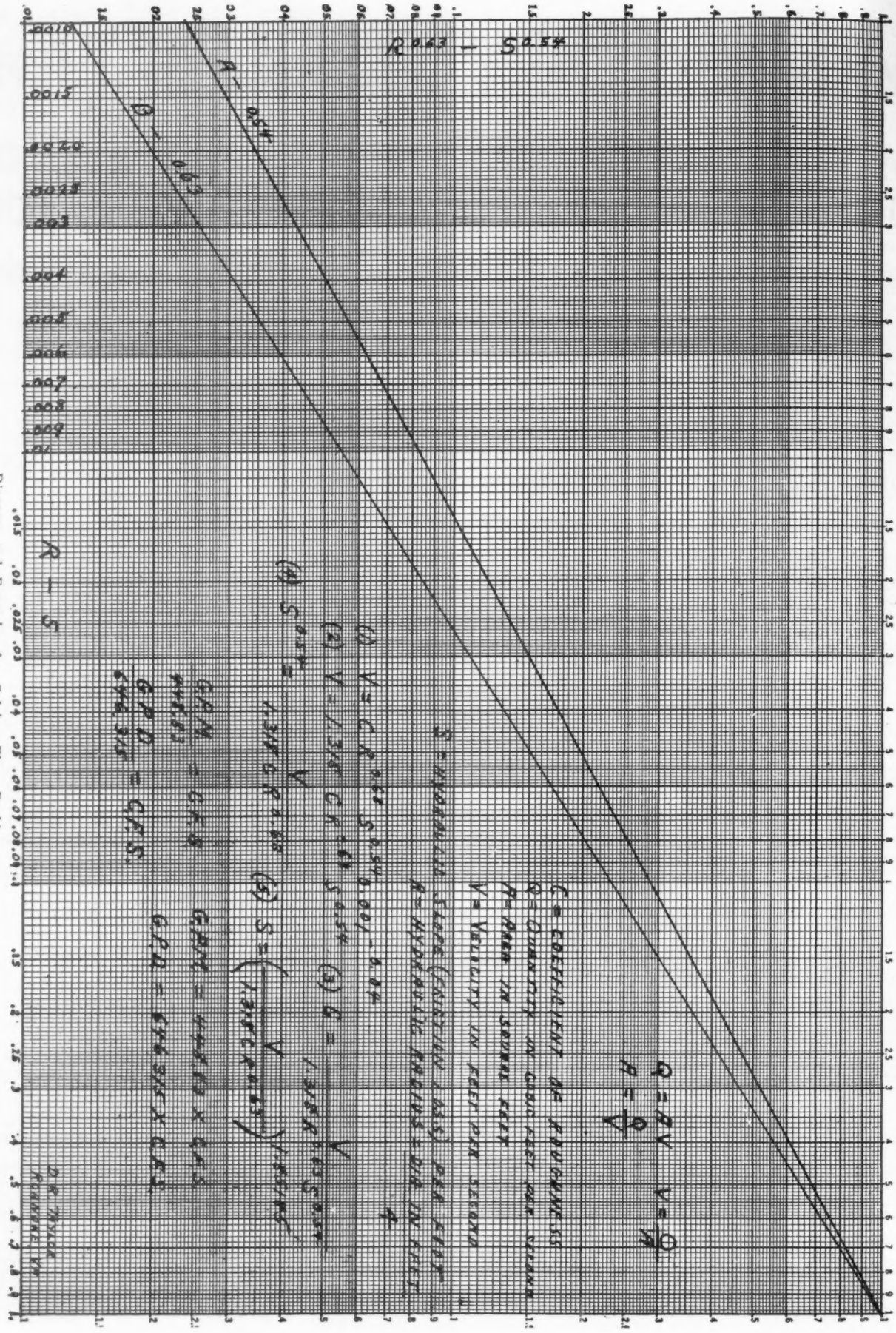

R = 0.63 − 0.55 S
R = 0.54
R = S
Q = AV V = Q/A
C = COEFFICIENT OF ROUGHNESS
Q = QUANTITY OF WATER IN CUBIC FEET PER SECOND
A = AREA OF WATER SECTION IN SQUARE FEET
V = VELOCITY IN FEET PER SECOND
S = EXPONENTIAL SLOPE (FRICTION LOSS) PER FOOT
R = HYDRAULIC RADIUS = A/P IN FEET
(1) K = C√(RS) S = K²/C²R R = K²/C²S
(2) V = 1.32 C √(RS) S = V²/1.32² C² R
(3) L = V/1.32 C √(RS)
(4) S = 1.32² C² R (5) S = (V/1.32 C √R)²
GPM = CFS × 448.8
GPM = 448.8 × C √R S
GPD = GPM × 1440
GPD = 646 320 × C √R S
DR. ROYCE
ROANOKE, VA.

Diagram and Formulas for Solving Flow Problems

or roots of numbers, and the decimal points are shown in each case. Furthermore, if all of this eventually leads to a complete comprehensive study of your entire distribution system, the purchase of an hydraulic slide rule (based on the Williams and Hazen formula) will be a good investment. With any great volume of hydraulic computations to be done, the answers can be rapidly determined with one of these rules, which is just as easy to use as the ordinary slide-rule.

CAST IRON PIPE DIMENSIONS
and Hydraulic Radius Values
TABLE 1.

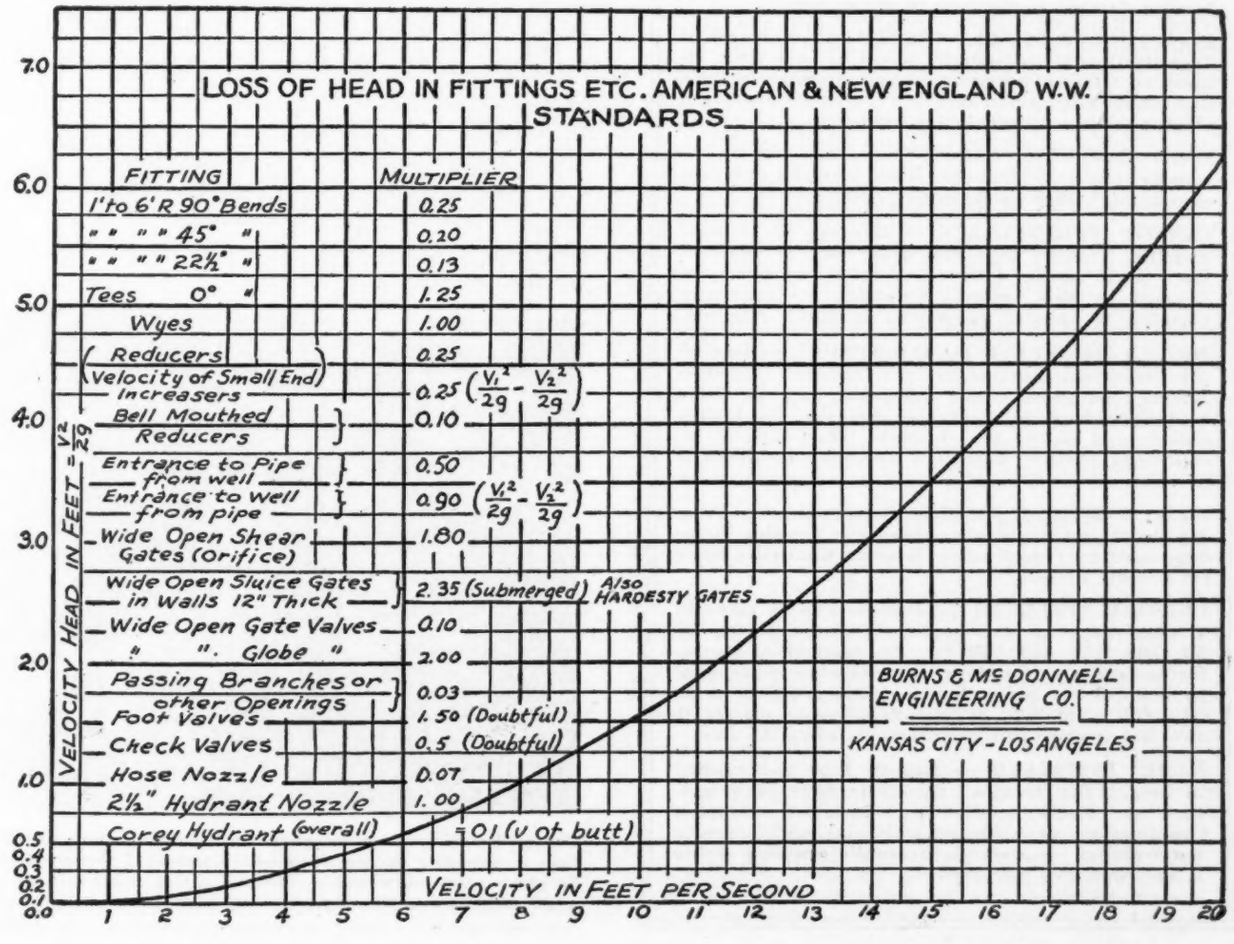
	Nominal Standard Dimensions All Cast Iron Pipe				Actual Standard Dimensions Pit-Cast Class B				Super Delavaud Class 150			
					Unlined		Cement Lined		Unlined		Cement Lined	
Nominal Diameter	Area Sq. Ft.	Diam. Feet	$R = \left(\frac{\text{Diam. Ft.}}{4}\right)$	$R^{.083}$	Area Sq. Ft.	Diam. Feet	Area Sq. Ft.	Diam. Feet	Area Sq. Ft.	Diam. Feet	Area Sq. Ft.	Diam. Feet
2".....	.0218	.1667	.0417	.135	.0218	.1667	.0192	.1562	.....	.....	.....	.....
3".....	.0491	.2500	.0625	.175	.0532	.2600	.0490	.2495	.0539	.262	.0495	.251
4".....	.0873	.3333	.0832	.209	.0915	.3418	.0825	.3240	.0920	.342	.082	.322
6".....	.1963	.5000	.1250	.270	.2060	.5120	.1890	.4900	.207	.513	.190	.492
8".....	.3491	.6667	.1665	.324	.3520	.6690	.3300	.6490	.367	.685	.346	.663
10".....	.5454	.8333	.2083	.372	.5420	.8300	.5150	.8100	.562	.8465	.536	.826
12".....	.7854	1.0000	.2500	.417	.7820	.9960	.7500	.9760	.812	1.016	.780	.996
14".....	1.069	1.1667	.2917	.460	1.065	1.1640	1.005	1.132	1.152	1.212	1.100	1.180
16".....	1.396	1.3333	.3330	.500	1.398	1.3320	1.332	1.302	1.500	1.382	1.440	1.352
18".....	1.768	1.5000	.3750	.539	1.768	1.5000	1.700	1.470	1.890	1.550	1.820	1.520
20".....	2.182	1.6667	.4167	.576	2.182	1.6670	2.100	1.635	2.340	1.725	2.250	1.692
24".....	3.142	2.0000	.5000	.647	3.142	2.0000	3.060	1.972	3.350	2.062	3.25	2.035
30".....	4.909	2.5000	.6250	.744	4.880	2.4950	4.720	2.451	....	....	....	....
36".....	7.069	3.0000	.7500	.834	7.080	3.0000	6.840	2.958	....	....	....	....

Loss of Head Through Valves and Fittings

(Burns and McDonnell)

To determine loss of head—Assume flow (Q) to be 5 cu. ft. sec. through a fitting of 12 inch diameter. From Q—AV the velocity (V) = 6.4 ft. per sec. From the chart, velocity head $\frac{V^2}{2g} = 0.7$ ft. Applied to 90 degree bend head loss is $0.25 \times 0.7 = 0.18$ ft. For a tee $1.25 \times .7 = 0.87$ ft.

(Note—Recent correspondence with the producers of this chart cites valves for check valves far in excess of the 0.5 indicated.—*Ed.*)


LOSS OF HEAD IN FITTINGS ETC. AMERICAN & NEW ENGLAND W.W. STANDARDS
FITTING
MULTIPLIER
1' to 6' R 90° Bends 0.25
" " " " 45° " 0.20
" " " " 22½° " 0.13
Tees 0° " 1.25
Wyes 1.00
Reducers 0.25
(Velocity of Small End) Increasers 0.25 (V1²/2g - V2²/2g)
Bell Mouthed Reducers 0.10
Entrance to Pipe from well 0.50
Entrance to well from pipe 0.90 (V1²/2g - V2²/2g)
Wide Open Shear Gates (Orifice) 1.80
Wide Open Sluice Gates in Walls 12" Thick 2.35 (Submerged) Also HARDESTY GATES
Wide Open Gate Valves 0.10
" " Globe " 2.00
Passing Branches or other Openings 0.03
Foot Valves 1.50 (Doubtful)
Check Valves 0.5 (Doubtful)
Hose Nozzle 0.07
2½" Hydrant Nozzle 1.00
Corey Hydrant (overall) = .01 (v of butt)
VELOCITY HEAD IN FEET = V²/2g
VELOCITY IN FEET PER SECOND
BURNS & McDONNELL ENGINEERING CO.
KANSAS CITY - LOS ANGELES

JOHNS-MANVILLE

Executive Offices: 22 E. 40th Street, New York, N. Y.

Offices in all large Cities

●

TRANSITE PRESSURE PIPE — TRANSITE SEWER PIPE

TRANSITE PRESSURE PIPE . . . *a brief discussion of how this asbestos-cement pipe can help you provide more efficient water service at lower cost—*

A SUMMARY OF TRANSITE PIPE'S OUTSTANDING CHARACTERISTICS

●

MADE OF ASBESTOS AND CEMENT — Transite Pipe is built up under tremendous pressure on a polished steel mandrel to form a homogeneous structure of great strength and uniformity.

RESISTANT TO VIBRATION—By virtue of its flexible joints, Transite Pipe is resistant to the shock and vibration of traffic; authoritative reports from abroad indicate the ability of flexibly connected asbestos-cement pipe to withstand indirect bomb shock with little or no effect on the performance of the line. Simplex Couplings divide the line into a series of flexible links which relieve the line of high flexural stresses and which have been found to localize damage in the case of direct hits.

EACH LENGTH RIGIDLY TESTED—Every length of Transite Pipe is individually tested to four times its specified rating in a hydrostatic test machine. In those sizes where flexural strength is important, each length of pipe is also subjected to a beam test.

HIGH CARRYING CAPACITY — Because of its smooth interior, Transite Pipe provides an unusually high flow coefficient, C=140.

CANNOT TUBERCULATE — Because it is nonmetallic, Transite Pipe can never rust or tuberculate. As a result, delivery capacity can never be reduced by this internal corrosion — expensive cleaning to remove tubercules is never required.

HIGHLY RESISTANT TO CORROSION — One of the important advantages of Transite's asbestos-cement composition and unusually low free-lime content is high resistance to corrosion — inside, outside and all the way through. Thousands of installations attest to Transite's durability in all kinds of soils.

TIGHT FLEXIBLE JOINTS—Composed of a Transite sleeve and two rubber rings, the Simplex Couplings used in Transite lines provide unusually tight, yet flexible joints.

UNIFORM STRENGTH — Transite Pipe is made in a wide range of sizes and in pressure classes of 50, 100, 150 and 200 lbs. Its method of manufacture and test procedure assure absolute uniformity in the finished pipe, thus permitting engineers to take full advantage of various pressure classes to meet varying pressure requirements along the line.

EASILY INSTALLED — Transite Pipe is furnished in long, 13-ft. lengths. Relatively light in weight, they are easily handled and installed. Simplex Couplings are assembled quickly and easily, even in wet trenches — a simple hydraulic coupling puller is the only tool required.

IN SELECTING a water pipe — whether for an extension or replacement of existing lines or the installation of a complete new system—careful consideration should be given to the basic factors contributing to the economic life of the pipe. For example:

DELIVERY CAPACITY . . .

Waterworks engineers generally agree that a water main, even though it remain structurally intact, may completely outlive its economic usefulness over a period of time. This point is reached when the pipe will no longer carry, economically, a sufficient volume of water to meet demand. Such a condition may arise from characteristics inherent in the pipe itself, from increased demand or from a combination of these two causes. Thus, in designing water systems, the engineer is faced with the responsibility of anticipating and solving these problems.

To compensate for expected reductions in carrying capacity, specifications often call for larger sizes of pipe than would otherwise be necessary. However, there is another, more fundamentally sound solution. In J-M Tran-

One of the hundreds of American Municipalities, where Transite Pipe is providing unusually efficient, economical water service. Transite's speed of assembly reduces the time trenches must be open—minimizes traffic congestion and inconvenience to business.

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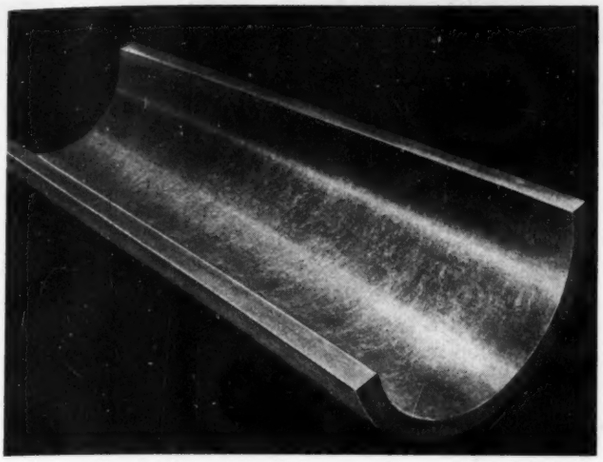


Because it is immune to tuberculation, wherever used, Transite Pipe assures an abundant supply of water through the years with low pumping costs.

Over 62,000 feet of 10-inch to 30-inch Transite Pipe were used on this water collection and transmission system. Because of its light weight and speed of assembly, the pipe was laid as fast as the trench was opened.

site Pipe, engineers find basic advantages that permit them to specify the most economical pipe sizes with full assurance that delivery capacity will not be reduced by tuberculation, the internal corrosion which, even when present in relatively small degree, greatly reduces the carrying capacity of ordinary pipe.

Transite Pipe is an asbestos-cement product. During manufacture, it is built up on a polished steel mandrel that imparts unusual smoothness to the interior wall. Its flow coefficient is conservatively established at C = 140. This means that Transite water lines start with an exceptionally high carrying capacity.

Transite's freedom from tuberculation means that pumping costs stay low, for pressures need not be increased to compensate for a steadily decreasing flow coefficient and resulting loss of head in the line. Not only does this advantage provide worthwhile operating economies, but in many cases it also permits the use of smaller diameter pipe with resultant savings in all the numerous items that go to make up the original cost of completed water lines.

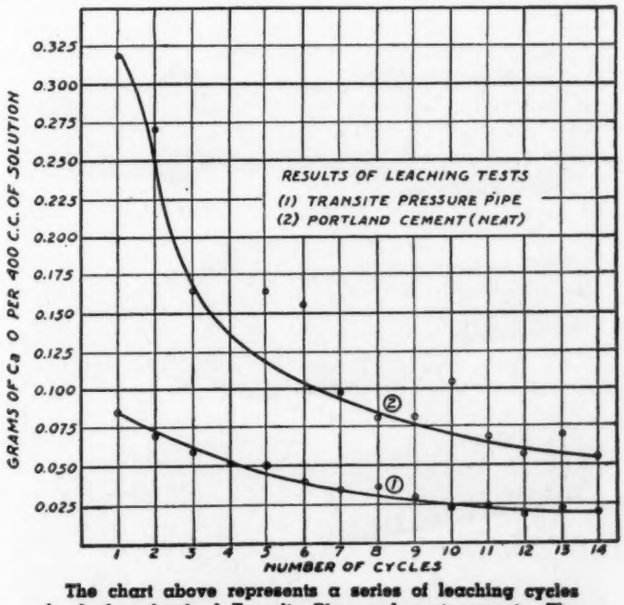
SOIL CORROSION . . .

Broadly speaking, most soil corrosion engineers agree that there are two principal forms of soil corrosion — chemical and electro-chemical.

Chemical corrosion is caused by the direct, corrosive action of acids and salts encountered in the soil. Transite Pipe, due to a special process of manufacture and treatment, is virtually inert to concentration of acids and salts ordinarily found in soils. Free lime which might generally be expected in cement products, has been largely converted to insoluble silicates due to the method of manufacture. A comparison of the two curves in the diagram below shows the high degree of insolubility of Johns-Manville Transite Pipe. It is for this reason that Transite is so highly resistant to all forms of chemical corrosion.

Electro-chemical corrosion is caused by the electrolytic action between ordinary pipe and materials in the soil. This action is similar to that of a simple electric cell. In this case, the materials in the soil represent the positive pole; the soil moisture, the electrolyte, and the pipe wall serves as the negative pole. The current generated passes from the pipe to the positive pole and causes a gradual disintegration of the pipe structure.

With Transite, however, this condition can never



The chart above represents a series of leaching cycles for both pulverized Transite Pipe and neat cement. The small amount of free lime extracted from Transite indicates that for all practical purposes it may be considered insoluble—one of the major factors responsible for its unusual resistance to soil corrosion.

JOHNS-MANVILLE

occur, because being non-metallic, Transite is a non-conductor—therefore absolutely free from electrical corrosion. Furthermore, this asbestos-cement pipe is immune to electrolysis caused by stray electric current from high voltage lines, streets, railways, etc.

The successful performance of Transite Pipe in all kinds of soil and under many varying climatic conditions provides practical proof of its high resistance to corrosion—inside, outside and all the way through.

JOINT LEAKAGE . . .

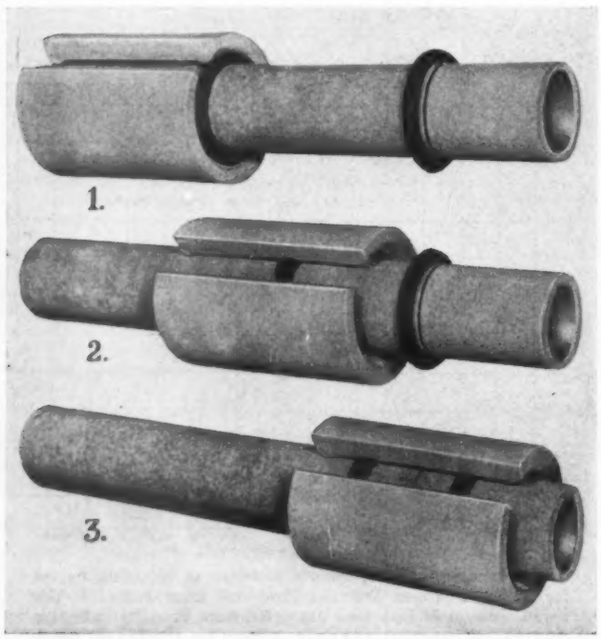
Numerous surveys have shown that leaky joints are responsible for a considerable portion of total water losses from underground mains. Generally recognized by waterworks men as a serious problem, joint leakage not only results in a direct waste of water but, by washing away supporting soil, frequently causes pipe to fracture under traffic and earth loads.

Much of this trouble is caused by the fact that the ordinary rigid joint, even though perfectly made by skilled workmen, may open up when subjected to vibration or settlement after the line is in service.

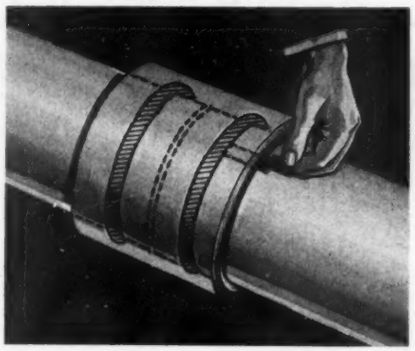
Such potential losses are minimized with a flexible joint. And that is the principle upon which the Simplex Coupling, employed in assembling Transite Pipe, was designed. Consisting of a Transite sleeve and two rubber rings, it forms a tight joint that stays tight in service. Its flexibility compensates for vibration and for vertical, longitudinal and lateral movements to which the pipe may be subjected underground. Depending upon the size of the pipe, a deflection of as much as 5° is possible at each joint.

From a practical standpoint, the less skill required in assembly, the less the danger of defective joints in the field. The dependability of the Simplex Coupling is due primarily to these distinctive features:

1. It is actually a pre-fabricated, "packaged" joint. The ends of each pipe and the inside of each coupling



Simplex Couplings Assembly (1) at start of operation (2) sleeve pulled over one ring, (3) final position, sleeve centered over joint.



With Simplex Couplings tightness of the joint can be determined from the outside as soon as the pipe is laid. A thin steel blade, slipped under the lip of the sleeve, checks the position of the rubber ring. If the position is right, the joint is tight.

are machined to specific dimensions. The rubber rings are precision-made and subjected to rigid inspection before shipment. Joints are assembled cold—no pouring, caulking or heating equipment is needed. A simple hydraulic coupling puller, loaned by Johns-Manville without charge, is the only tool required for assembly.

2. The effectiveness of the joint does not depend on the individual skill or training of the workmen. So simple is the operation that perfect Simplex joints can be made quickly and economically even by unskilled crews.

Made of Permanent Materials. The Transite sleeve, like the pipe itself, is made of asbestos and cement and has the same high degree of resistance to all forms of corrosion. The rings, made of the highest quality rubber, are carefully cured and specially compounded with anti-oxidents and properly graded non-hygroscopic fillers to assure permanence in water service.

INSTALLATION . . .

One of the major factors contributing to initial cost of a pipe line is the time and equipment required for installation.

Transite Pressure Pipe offers primary advantages that help speed up installation and cut costs. The long, 13-ft. lengths are relatively light in weight. Two or three men can easily lower 8 inch pipe into the trench by hand. In fact all but the very largest sizes can be handled without the use of mechanical equipment.

Simplex Couplings are assembled cold just as they are received from the factory. Wet trenches present no problem for no heating or caulking equipment is required. And the complete assembly is completed in much less time than required by ordinary types of joints.

WRITE FOR COMPLETE DETAILS

A detailed discussion of the economic factors contributing to efficient, low-cost water lines is given in the Transite Pressure Pipe Brochure, TR-11A. The 76-page "J-M Pipe Installation Manual," D. S. 332, outlines effective methods of installing water lines and includes much more data on Transite Pipe and the Simplex Coupling than was possible to include on these pages. For detailed data on making repairs to transite lines damaged by enemy action the booklet, "Transite Pipe—Repair of War Damage" will be found helpful. It is profusely illustrated and contains numerous diagrams and data pertinent to the maintenance of flow in the event of hostilities. For your free copy of these three books, write to Johns-Manville, 22 East 40th Street, New York, N. Y.

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IN YOUR SEWAGE DISPOSAL SYSTEMS - - -

Transite Sewer Pipe offers fundamental advantages that help reduce the cost of sewer line construction, maintenance and operation.

TRANSITE PRESSURE SEWER PIPE

Pressure Sewer Lines are very similar in operation to water lines and must meet the same general service requirements. In addition, the pipe must be highly resistant to the corrosive action of the sewage. Transite Pressure Sewer Pipe, which is made of the same durable asbestos-cement composition as Transite Water Pipe, described on the preceding pages, meets all these requirements and provides highly satisfactory service in systems of this type.

TRANSITE GRAVITY SEWER PIPE

Gravity Sewer Lines offer a number of specialized problems which Transite Gravity Sewer Pipe meets eminently well. For example:

INFILTRATION—

It has been authoritatively estimated that as much as 25% of the contents of the average sewer is ordinary ground water that enters the system by infiltration through the joints. And it costs practically as much to treat this water at the disposal plant as it does to treat sewage itself. Furthermore, in many cases, engineers must allow for this huge quantity of water by specifying a larger diameter pipe than would otherwise be necessary.

With Transite Sewer Pipe, however, the infiltration of ground water presents no serious problem. Transite's long 13-ft. lengths cut down the number of joints in the line, thus reducing the danger of infiltration right at the start. The poured sleeve joints employed in Transite lines are unusually tight and stay tight in service. The jointing compound is the highest quality, unfilled asphalt which, when set, provides a strong, flexible joint that is highly resistant to cracking or shrinkage. As a result, Transite Sewer Pipe lines have considerably less infiltration than that allowed by most specifications.

Transite, the corrosion-resistant, asbestos-cement sewer pipe, answers every requirement of efficient sewerage service. Its long 13-ft. lengths make laying to exact grades a quicker and more accurate job. And the tight joints employed minimize infiltration.

CARRYING CAPACITY

One of the most important factors in any sewer line is carrying capacity. All other things being equal, the relative carrying capacity of two or more types of pipe is best indicated by their flow coefficient. If, for example, the inside of the pipe is rough and uneven, the flow velocity is low and carrying capacity is greatly reduced. A smooth pipe, however, has a high flow velocity and a correspondingly high carrying capacity.

Transite Sewer Pipe has an unusually smooth interior surface, its conservative friction coefficient when installed at the usual sewer pipe grade is N=.010. This high carrying capacity results in savings that can be taken in one of two ways. Flatter grades may be employed during installation — reducing the depth of the trench and making installation a faster, more economical job. Or, when the usual sewer pipe grade is maintained and deep trenches present no problem, Transite's high flow velocity often makes it possible to use a smaller diameter pipe without reducing the desired carrying capacity of the system.

OTHER CONSIDERATIONS

Resistance to corrosion, structural strength and ease of installation are, of course, other important considerations in the selection of sewer pipe.

Because of its asbestos-cement composition and its unusually low free lime content, Transite Sewer Pipe is highly resistant to the corrosive action of all types of domestic sewage and most industrial wastes—inside, outside and all the way through.

Transite Sewer Pipe is furnished in sizes from 4" to 36" in Class I, from 10" to 36" in Classes II and III and from 18" to 36" in Class IV. Each class of pipe is made to a specific crushing strength, thereby providing for the selection of the most economical combination of classes of pipe to meet the specific strength requirements of the line.

The long 13-ft. sections in which Transite is furnished eliminates many of the difficulties in installation common to ordinary short length sewer pipe. Relatively light in weight, these long lengths cut down handling costs. More footage may be carried per truck load to the trench and fewer men are needed to install the pipe. These long lengths also reduce the number of joints that must be made and thus save considerable time and labor. In addition, long lengths greatly facilitate laying the pipe to an accurate grade.

It will pay you to get further details about this modern sewer pipe. Brochure TR-21A presents them in brief, quickly read form. The "Transite Sewer Pipe Installation Manual" D.S. 342 gives valuable information and tabular data pertinent to installation problems. Write for these from Johns-Manville, 22 East 40th Street, New York, N. Y.

JOHNS-MANVILLE JM PRODUCTS

PUMP POUNDING CORRECTED BY SIMPLE "AIR SNIFFER"

By D. R. TAYLOR, Plant Superintendent
Roanoke Water Department, Roanoke, Virginia

THE annoying dull pounding on the accentuation of pulsations, as the lesser of the two evils in the operation of piston pumps, is usually the result of a deficiency of air in the cushion chamber on the discharge end of the pump.

To eliminate this deficiency it is not necessary to go to the expense of installing an air compressor. The trouble can be eliminated much more inexpensively by the installation of a simple anti-"pulsationitis" gadget which we have dubbed our air "sniffer." The accompanying sketch pictures the installation which should be made from readily procurable parts, as follows:

There is probably a plug or a drain pipe in the bottom of your pump casing. Install a ½ in. line (A) from this point to a point slightly above the top of the air chamber with a renewable seat globe valve (B) in this line. The length of a nipple below the top of it is a good location.

At the top of this line, install a tee (C) with the side outlet looking down, and after drilling and tapping the top of the air chamber, connect one end of this tee to the top of the chamber with another globe valve (E) and a check valve (D) between the tee and the chamber. This check should open for a flow toward the chamber.

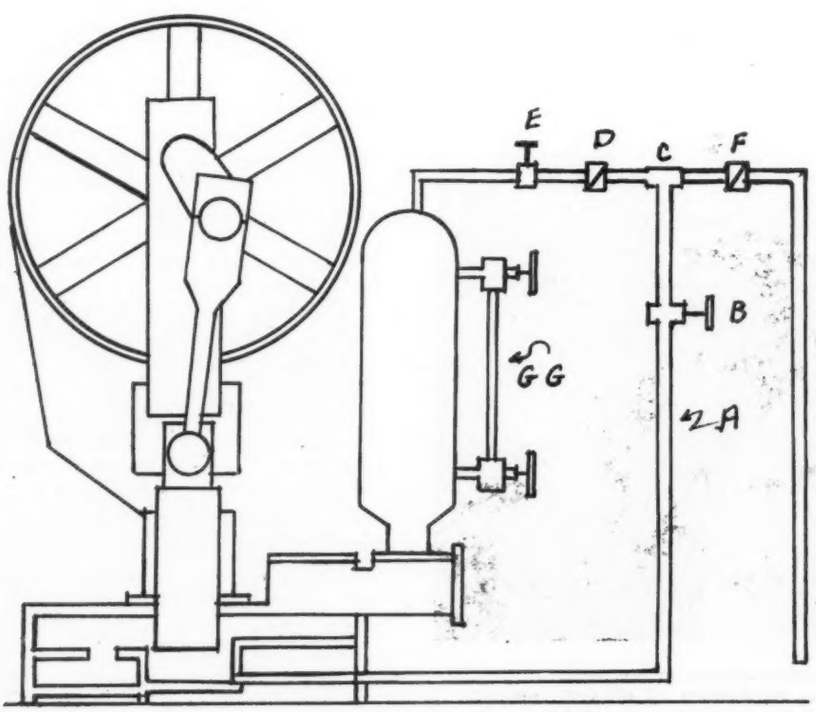
At the other end of the tee, install a 6 in. nipple and another check valve (F), also set for a flow toward the chamber. Complete the line with a short nipple, a 90 degree elbow, and a length of ½ in. pipe dropping almost to the floor. This is done so that any drippings from this line will be near the floor and, therefore, will not spatter your pump room and equipment.

Then purchase from your local mill supply dealer a gauge glass (GG) and install it on the side of the air chamber for an easy and quick determination at any time of the quantity of air in the chamber.

When the air needs replenishing, open valves (E) and (B) and the pump will do the trick automatically. On the up or suction stroke of the pump plunger, check valve (D) will remain closed, check valve (F) will open, of course, and air will be drawn into line (A). On the down stroke, check valve (F) will close and check valve (D) will open. The charge of trapped air will be forced into the air chamber.

Let me warn you, however, that this little gadget is much more vivacious than you might at first suspect. Only a few minutes are required to fill the chamber and, if the "sniffer" is allowed to operate too long at one "sitting," you may experience the annoyance of having too much air, possibly to the extent of aerating your transmission or distribution main. With a little experience, you will soon be able to determine the necessary frequency and length of time to operate the "sniffer" to satisfy your particular conditions, and then you can cross off another item from your headache list.

We have successfully operated one of these gadgets on a five million gallon per day steam pump and one on a nine hundred thousand gallon per day motor driven triplex pump for a number of years with perfect satisfaction.



Sketch showing the method of installation of the "sniffer" on a triplex plunger pump

THE NATIONAL WATER MAIN CLEANING COMPANY

Contractors for Cleaning of Water Mains

22nd Floor, 30 Church St., New York, N. Y.

BRANCHES

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501 Howard St., San Francisco, Calif.
2028 Union Ave., Montreal, Can.

THE NATIONAL METHOD

THE METHOD

The National Method of water main cleaning consists of passing a machine through the main which removes tubercles, incrustations and deposits from the pipe lining. This machine is either water-propelled or cable-drawn through the water main. Thorough cleaning can be accomplished by this method at the rate of approximately 50 to 100 ft. per minute, in sections of from several hundred feet to several miles depending upon conditions.

Briefly, the method involves cutting the pipe in two places, for entry and exit of the cleaning machine, inserting the machine; placing a riser pipe at the exit through which first the muddy water and then the machine emerge; propelling the machine by pressure or by cables through the pipe; finally shutting off the water, removing the riser pipe, and reconnecting the main.

The total time required for shutoff of water in any district is five to seven hours. In an emergency, the pipe can be temporarily made up and service resumed. The work can be done at night if desired.

20" Main in a Midwest City Before Cleaning.

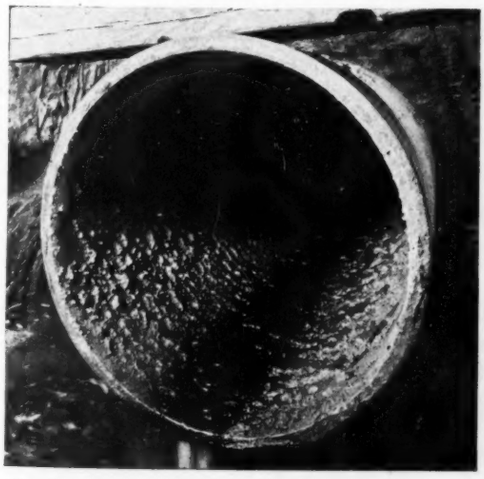
THE RESULTS

The National Method is guaranteed to restore the carrying capacity of pipe to at least 95 per cent of that of new main (The actual result is usually very close to 100 per cent.)
The National Method gives you:

1. **Greater delivery**
2. **Lower pumping costs**
3. **Reduced insurance rates**
4. **Clean water**

LET US CLEAN OUT YOUR CLOGGED MAINS

National experience makes satisfactory cleaning certain. National men know how to meet and overcome unforeseen difficulties that may arise.



When a Pipe Lining Is Tuberculated to This Extent, the Frictional Resistance to Flow Is Considerable.

Machine Arrives at End of Run After Cleaning 30" Main in St. Louis

Information regarding any of the hundreds of successful cleaning projects will be supplied upon request.

FLEXIBLE UNDERGROUND PIPE-CLEANING CO.

A DIVISION OF FLEXIBLE SEWER-ROD EQUIPMENT CO.
9059 Venice Boulevard, Los Angeles, Calif.
401 BROADWAY, NEW YORK • 1624 HARMON PLACE, MINNEAPOLIS • PICKWICK BLDG., KANSAS CITY

A New, Low Cost Method of Keeping Water Mains Clean

Operation

Inclined risers are installed at certain selected locations. These risers terminate in a concrete lined surface box with manhole cover and are normally plugged with a special "Flexible" plug. During cleaning operations a metal gate is inserted at the lower end of the riser to guide the flow of "cleanings". A Flexible sewer-rod is threaded down one riser, along the main and out through the prepared riser. A Flexible cleaning unit then drawn through the main forces out the accumulated scale, sediment and any other deposits which may have formed in the main. Flexible engineers will be glad to specify the proper locations for the inclined risers.

Advantages

Installation of new pipe or relining due to clogging is avoided.

The cleaning operations can easily be handled by the normal maintenance crew.

The operation is simple, quick and economical.

Full main capacity is easily maintained for the full life of the pipe.

The water main system is kept in a more sanitary condition.

Compare these estimated costs, based on 50-year cost of operation—6-in. pipe:

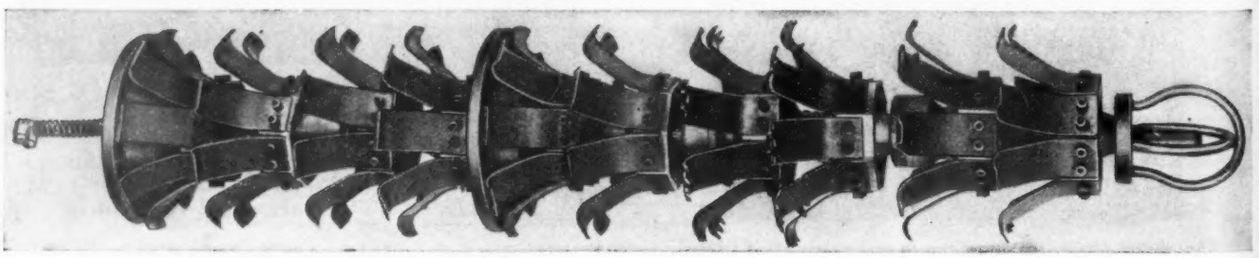
1—NEW PIPE—$3.00 per ft. + 2% per year for interest on investment. . . . $6.00 per ft.
2—RELINING—$1.00 per ft. + 2% per year for interest on investment. . . . $2.00 per ft.
3—OCCASIONAL CLEANING by NEW, FLEXIBLE METHOD. . . . . 40c per ft.

Underground Pipe Cleaning by "Flexible" Contract

Water Supply Systems
Refineries
Railroads
Process Industries

The Flexible Underground Pipe-Cleaning Company operates in all sections of the country. Contracts are accepted for the cleaning of any kind of underground pipe. Our workmanship and responsibility are attested by customers whose names will gladly be furnished on request.

THE PRESSURE LINE SCRAPER



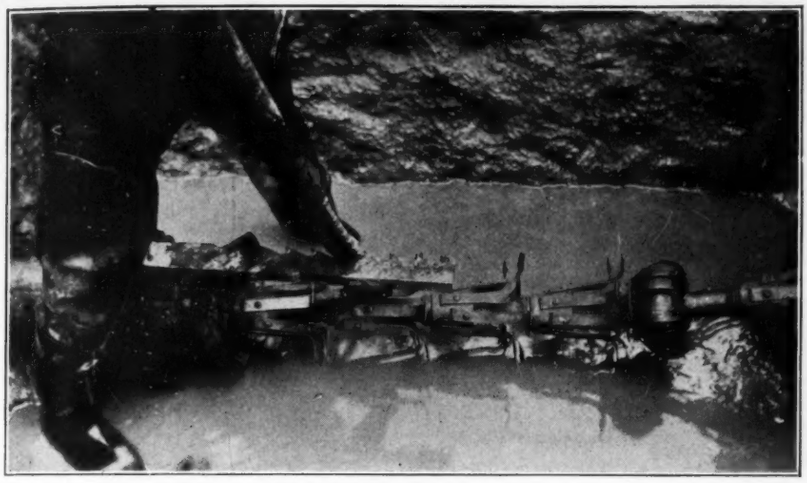
WATER MAIN CLEANING

Some Recent Experiences and Results

By WM. S. STAUB, Engineer

West Virginia Water Service Co.
Charleston, West Virginia

WE HAVE just completed main cleaning projects at three of our properties in this state. This, our first adventure in this kind of main restoration, will serve as index of merit of the process. We have definitely raised the flows and pressures in those mains that have been cleaned and, in cases of the transmission mains, the pumping cost per million gallons has been reduced.



"Jacking-In" Operation
About half of a cleaning tool jacked into an 8-in. main. It will travel under its own "steam" by main pressure turned in behind it.

The purpose of this paper is to present our ideas of main cleaning, why we clean mains, what results we have had, the cost per foot to clean; to give a general description of the procedure and to observe what happens in a cleaned main.

In years gone by, when there was no water treatment or when the practice was in its infancy, beyond taste and appearance other characteristics of the water were given little thought. Therefore the distribution system suffered, due to lack of knowledge of corrective treatment. Th edeposition of the solids and the tuberculation reduced the area of the pipe and, therewith, the amount of water that would flow through the pipe under pressure available. Consequently, today, when there are complaints of poor pressure, or when increased fire flow is in demend, we are faced with the problem of main replacements or improvement of existing mains. Although the exterior of the pipe is usually as good, practically, as the day it was installed, the interior may present a scene comparable to the stalagmites and stalactites of the eastern caverns. If such choking deposits can effectively be removed from the pipe and the carrying capacity appreciably restored there will be a great savings over replacements, even though the latter be necessary eventually..

A dirty main is definitely a liability. From the operating standpoint a dirty transmission main consumes many kilowatt hours of power due to the added friction. Kilowatt hours in turn cost money, which in turn increases operating expenses. A dirty main is a great handicap to the fire departments, due to insufficient quantities of water. Poor pressure complaints from consumers are not soothing melodies to a superintendent's ears. Consequently, everyone suffers from the effects of tuberculated pipes.

Locating the Trouble

When a main is suspected of being tuberculated, or when we find that the operating head on a pump is much greater than the static head plus the calculated friction head for new pipe, it is time to find the trouble. The distribution main is isolated in such a manner than all water going to a certain area must pass through the section of pipe to be tested. Then, in the early morning hours, the calibrated pressure gauges are placed along the line and a hydrant is opened at the end of the line. The amount of water is measured with a pitot-tube, the pressure drop is recorded and the loss per 1000′ or the value of "C" is determined. (For details of the method see "Hydrant Discharge Measurements," page 183. Reference and Data Number of Water Works and Sewerage, May, 1939.)

We admit this method of determining "C" is not as accurate as secured by Pitometer tests, but we feel that a reasonably accurate value is obtained if precautions are used. In the case of transmission mains, by determining the efficiency of the pumping equipment, static head, operating head, power consumed, water pumped, it is possible to get a very good check over any period. (For "A Simple Method for Checking Pump Efficiencies" see page 445, November, 1939, Water Works and Sewerage.)

Cleaning Procedure

The largest pipe which we cleaned was 10″ cast iron. The 10″ and 8″ pipe was cleaned with the pressure cleaning machine, which uses the water pressure to push the device through the pipe. This machine (see pictures) is about 6′ long, composed of five cutting heads and two pistons. The heads are "vertebrae" upon which are attached, around the circumference, the cutting blades. The

The "Carrier"
A rod with leather piston cups is used to thread cable through 4-in. and 6-in. mains.

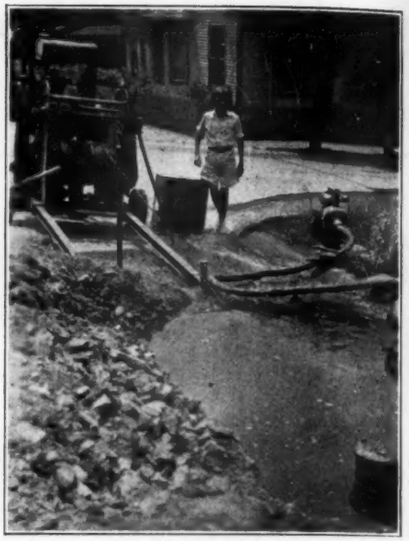
blades are of spring steel. There are two flexible "pistons" from which the machine gets its drive. There are adjustable ports through the pistons, which we can set to control the volume of water passing the machine for sweeping the debris ahead and, at the same time, to prevent the machine from moving too rapidly. Closing the ports naturally gives added driving power for the tougher jobs. The pistons and cutting heads are on a flexible spring and cable type of shaft. Its flexibility will allow the machine to pass a standard 90° bend. Contrary to the belief of many, the machine does not take on any spiral or whirling motion in its travel.

Cleaning 8 and 10 Inch Mains

The main is isolated and a section of pipe is removed at the point of beginning. This section should be long enough to give ample working room for inserting the machine. The machine is then jacked intothe pipe (see cut) and the pipe permanently jointed either by solid or Dresser sleeves. At that point at which we wish the machine to emerge the pipe is again cut. A short section is removed and bell and spigot fittings are used to rig a riser. Usually this is done with a 45° bend and a short piece of pipe. The joint need only be juted and chained. The purpose of the riser is to discharge the debris on top of the ground, rathre than in the trench. When the riser is rigged the pipe is all ready. The valve on the main is opened slowly to secure the proper amount of water and the machine begins to move. The machine generally moves about 100 feet per minute and it is possible to follow its travel through the line, as the water passing the pistons and the scraping blades is audible at the surface. Generally the water emerging from the riser will only be colored until the machine gets within about 300 feet, then the water is thick and black. The solid material may issue from the pipe like sausage, if the encrustation is marked. In the case of the 3900′ of 10″ line in South Charleston (W. Va.) there was an estimated one and one-half tons of solid material which came from the pipe. The machine will generally lodge in the riser pipe due to so much debris, and has to be helped out. When the machine has reached its destination (after only one trip through in most cases) the riser is dismantled, the main flushed, jointed, and placed in service.

Dollar Losing Debris

Some of the 1½ tons of solid material swept out of 3,976 ft. of 10-in. transmission main, to reduce pumping cost $2.37 per million. (See accompanying tables of data and costs.)



The Safety Winch

Pulling cleaning tool through a 4-in. line. In such operations the debris collects in the ditch, which is dewatered with the small portable pump alongside.

A Small Line "Make-Up"

In which the "carrier" with threading cable attached has been inserted in 4-in. main and is ready to travel.

Cleaning 4 and 6 Inch Mains

In the case of 6″ mains, where they are not so dirty, these may be cleaned by "pressure shots" as described for larger sizes of pipe. In one case where the pressure was low a booster pump was used to supply increased pressure for a 6″ "pressure shot." However, generally 6″ mains must be cleaned the same way as 4″ pipe, which I will now describe.

In cleaning 4″ mains the section to be cleaned is isolated and the main opened at both ends. At the beginning point a small cable is attached to a "carrier" and inserted into the line. The "carrier" is a short rod with leather pistons. The main is then jointed at this point with a portable coupling known as a "make-up." This "makeup" has a gland in the top through which the small cable may be fed. The water is then turned on behind and the water velocity takes the "carrier" and the small cable to the other end of the pipe. This small cable is then used to pull the big cable back to the point of machine insertion. The makeup is removed, the cleaning tool clamped to the large cable (see cut), the main permanently jointed, the water pressure turned on, and the cleaning tool is pulled through the pipe by a gasoline driven winch. This process is much slower than the pressure method and great care must be exercised to prevent breaking the cable and losing the machine. In this case a very slow speed is used. The winch automatically releases the clutch when the tension or pull becomes too great. This generally happens when the cleaning tool caught some joint lead or a bad obstruction. When the cleaning tool emerged the main was flushed and permanently jointed.

Obstacles Encountered

In pressure cleaning the drive of the machine is dependent upon the velocity of the water acting on the pistons, and in the event the machine encounters a cross increasing on the branches it will generally stop. In other words, in cleaning an 8″ pipe, if at an intersection an 8 x 10 inch cross is present the machine will hang. This is due to the pistons expanding and allowing the water to pass it instead of driving the machine.

If the wash water passing the machine is not sufficient to carry the debris ahead the machine will be fouled. We encountered one 8″ main in which the machine would move a short distance, then stop. After the wash water had moved the material ahead the

machine would move again. This happened on a long line where wash water was insufficient and blowoffs were too far apart. The machine had to re-run through this section and I am of the opinion that part of the debris was deposited behind the machine during the first cleaning.

Short radius bends with valves on one side caused several cuts to be made.

Insufficient pressure was a jinx on one job. We were cleaning a 10" main from the reservoir down the hill. The pressure at the point of beginning was only 17 pounds. Thus it was necessary to fill the line with water and bleed it rapidly at the bottom of the hill, thus creating a vacuum. When this was done it was then impossible to keep up with the machine.

Poor joints were responsible for a number of worries—poorly juted joints where the lead had run into the pipe. There were chunks of lead removed weighing 50-75 pounds, old pump gaskets, coil springs, timbers, rocks and, in one case a piece of 1½" pipe about 6 feet long. These had probably entered the system years ago when reservoirs were uncovered or when the pipe was laid.

An Ounce of Obstruction; A Pound of Cure

This section of 8-in. pipe didn't look "too bad," but results after cleaning showed that it was. Proof found in the accompanying tables of data, revealing the "before and after" story, is more convincing than many words about it.

Discoveries and By-Product Values

At Hinton practically the entire system was cleaned. As a result, the method in which tie-ins are made, the fittings, and location of mains were definitely established. I know that our superintendent there can now point out on the ground just what is at every intersection, because he made intersection cards accurately during the cleaning.

There were cases when a pipe which was supposed to be was not and vice versa. Old valves were found. some with box and all gone, some with stem broken and some found partly closed.

If anyone operating a water system, which has been in service for a number of years, attempts a job of main cleaning, he will probably be surprised at a great many things found. And, from the operating standpoint, the knowledge gained during cleaning of mains may well save a few nights sleep to the superintendent.

Conclusions

We feel that our main cleaning jobs have done a lot of good. Those who have seen the mains before and after know that flows have definitely been improved. Just how long this pipe will remain clean is another question, but we expect to keep a close check on the cleaned mains. In fact, we are taking daily samples at all points where we cleaned and are recording the pH, alkalinity and CO_2. Periodic flow tests will also be made to ascertain to what degree the main is tuberculating. We are trying to control our corrective-water treatments accordingly.

We do know that the fire flows have been greatly increased and that once weak hydrants are again gushing brisky. On transmission mains there have been definite and pleasing reductions in power consumed.

Costs and Cleaning Data

In the accompanying tables something of the data pertaining to cleaning operations and costs are presented for the benefit of those interested.

TABLE 1—Charleston Main Cleaning

Item	Pipe 6" Kanawha St.	Pipe 8" Va. St.	Pipe 10"* So. Chas.	Pipe 10"-8"** Nitro Line
Contract of Cleaning	$134.80	$271.70	$397.60	$1,488.95
Material Cost	6.19	48.86	138.29	250.40
Labor Cost	65.86	186.80	188.14	888.09
Total Cost	206.85	507.36	724.03	2,627.44
Number of Feet Cleaned	1348	2717	3976	29779
Cost per Foot	$ 0.1535	$ 0.187	$ 0.1823	$ 0.0834

* This cost does not include 8" temporary steel line which was laid. The rental of pipe, placing and removing cost $1,757.75 for 4200'. If this were added to the above the cost per foot for cleaning the 10" main would be $0.625.

** The 10" and 8" main is a transmission main and was cleaned as one unit. Therefore there was no breakdown in cost.

TABLE 2—Charleston Main Cleaning (Transmission Main)

Location	Size	Feet of Pipe Cleaned	"C" Before Cleaning	"C" After Cleaning
South Charleston	10"	3,976	66	130*
Nitro-Dunbar	10"	10,679	49	130
Nitro-Dunbar	8"	19,100	49	126
Charleston-Virginia St.	8"	2,717	—	138
Charleston-Kanawha St.	6"	1,348	—	115

* Yielding an estimated savings in pumping cost (power) of $2.37 per M.G. for the South Charleston main.

TABLE 3—Hinton Main Cleaning (Total Cleaning Costs)

Item	10" C.I.	8" C.I.	6" C.I.	4" C.I.
Contract of Cleaning	$177.40	$ 546.90	$255.60	$ 675.80
Labor Costs	42.92	238.33	185.60	376.86
Material Costs	44.25	245.54	189.30	301.96
Total Cleaning Cost	264.57	1,030.77	630.50	1,354.62
Cost per Foot	0.15	0.189	0.246	0.20

TABLE 4—Hinton Main Cleaning

Pipe Size	Ft. of Pipe Cleaned	No. of "Shots"	Max. Length "Shot"	Min. Length "Shot"	Ave. Length "Shot"	"C" Before Cleaning	"C" After Cleaning
10"	1,774	1	1,774'	1,774'	1,774'	—	128
8"	5,468	9	1,072'	215'	608'	48	126
6"	2,556	7	675'	189'	365'	80	117
4"	6,758	14	965'	36'	482'	44	122

TABLE 5—Sutton Main Cleaning

Item	Pipe 6" Main St.	Pipe 4" Town Hill	Pipe 4" South Side
Contract of Cleaning	$177.00	$325.40	$487.50
Material Cost	18.55	72.60	105.60
Labor Cost	90.50	166.40	249.20
Total Cost	285.85	564.40	842.30
Number of Feet Cleaned	1770	3254	4875
Cost per Foot	$ 0.161	$ 0.173	$ 0.172

TABLE 6—Sutton Main Cleaning

Location	Size	Ft. Pipe Cleaned	"C" Before Cleaning	"C" After Cleaning
Main Street	6"	1,770	42	136
Town Hill	4"	3,254	68	118
South Side	4"	4,875	71	117

COMPRESSED AIR FLUSHING OF SMALL MAINS

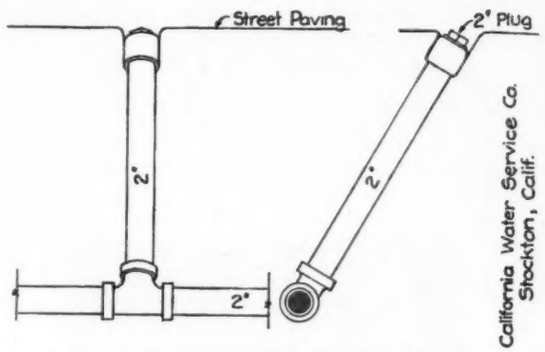
By R. F. BROWN

Plant Manager, California Water Service Co., Stockton, California

MANY water systems in the older California towns, like Topsy, just grew without any suggestion of planning for the future. Stockton was no exception. As a consequence we found ourselves with a great many 2-inch lines in the thinly populated areas.

We have for many years followed the practice of flushing small mains and all dead ends regularly by opening fire hydrants and flusher valves and simply allowing the water to flow from the main under normal pressure of 45 pounds until the main is apparently clear. Under this program all dead ends and all small mains are given ordinary flushing, approximately at intervals of every two months.

This method, however, does nothing but freshen the water in the dead ends and small mains. In order to effect a more lasting cure for taste and odor complaints, we decided to try boosting the pressure in the main with air to attempt to break loose more of the troublesome algae and other deposited material that attaches to the pipe wall. All of our dead ends, regardless of size, and at least every other block of our 2-inch lines have what we call flusher-risers installed for the convenience of our periodical flushing program—see sketch.



RISER CONNECTION TO 2" MAIN FOR FLUSHING

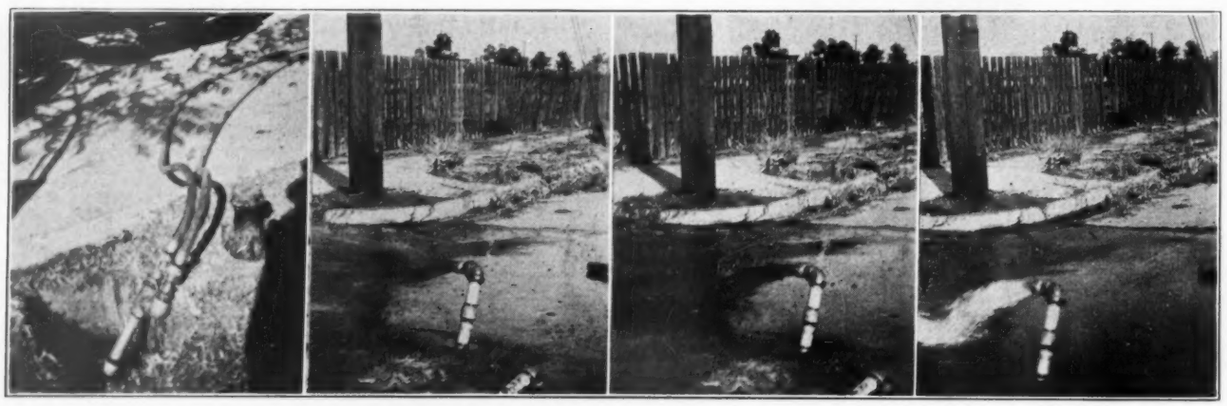
pose and it is economical, because the equipment required is only a portable air compressor and an air storage tank to provide a volume of air under pressure. No expensive cutting of mains or pavement is required and most jobs can be handled with a three-man crew.

When we first started this system we cleaned 40,000 feet of line, mostly 2-inch, over a period of two months. The cost was from 60 to 90 cts. per hundred feet, depending upon the number of services which had to be shut off and turned on again.

The success of this method of flushing is measured by the almost complete absence of the usual recurring taste and odor complaints from consumers served by mains thus treated. It is problematical how soon we will have to repeat this treatment, because from no consumer on the first line so treated has there yet developed a recurrence of complaints.

A secondary result, not anticipated, is the increase in carrying capacity of the 2-inch lines brought about by the loosening and blowing out of a great deal of scale. Thus has resulted a reduction in complaints of poor pressure as well as the taste and odor complaints.

A Self-Told Story



Air Lines Connected (This Time Through House Service at Curb Line)

First 90 Lb. Air Shot. (Note Extension Attached to Flushing-Riser)

First 45 Lb. Water Flush. (No Argument About Need to Eye or Nose)

Clear Water (Shooting and Flush Repeated As Indicated)

Air Flushing Operations

Compressed air is put into the line through a service connection midway between two flusher-risers after we have first closed the shut-off valves on the intervening services. The valve on the flusher-riser is then opened. All water in the line is forced out through the riser, by air under 90 pounds pressure. As soon as the air has expelled all the water from the line it is shut off and water under our ordinary pressure is run through the line to sweep out, through the flusher-riser, all particles of scale, sand or foreign matter that have been loosened by the air "shooting." We proceed in this manner alternately turning into the line air under 90 pounds pressure and water at 45 pounds until the flushing water leaving the risers no longer carries with it any scale or other foreign matter.

This system is apparently successful in accomplishing our pur-

SCHRAMM, INC.

PORTABLE AND STATIONARY
AIR COMPRESSORS

Main Office and Factory - WEST CHESTER, PA., U. S. A.

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AKRON, OHIO.....205 Emmon Avenue
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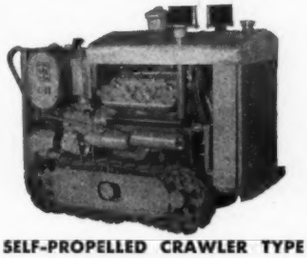
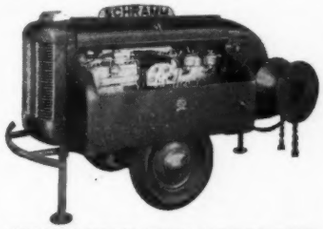
BOSTON, MASS.....130 Needham Street
BUFFALO, NEW YORK.....298 Dewey Avenue
CHICAGO, ILL.....2020 W. Walnut Street
CLARKSBURG, W. VA.....212 Ohio Avenue
DALLAS, TEXAS.....1300 McKinney Ave.
DENVER, COLO.....Sixth & Acoma Streets
DETROIT, MICH.....6331 Tireman Avenue
DULUTH, MINN.....210 E. First Street
INDIANAPOLIS, IND.....1900 Northwestern Avenue
KNOXVILLE, TENN.....817 Winona Ave.
LITTLE ROCK, ARK.....115 N. Spring Street
LOS ANGELES, CALIFORNIA.820 S. Santa Fe Ave.
MEMPHIS, TENN.....269 S. Front Street
MILWAUKEE, WISC.....4603 West Mitchell Street
MINNEAPOLIS, MINN.....514-520 Second St., S. E.
NASHVILLE, TENN.....309 Seventh Ave., S.
NEW HAVEN, CONN.....1881 Dixwell Avenue
NEW YORK CITY, NEW YORK.....90 West Street
OMAHA, NEBR.....1516 Leavenworth Street
PHILADELPHIA, PA.....3719 Filbert Street
PHOENIX, ARIZONA.....1401 S. Central
PITTSBURGH, PA.....512 Columbia Building
PORTLAND, OREGON.....1233 N. W. 12th Avenue
PROVIDENCE, R. I.....750 Reservoir Avenue
RICHMOND, VA.....12 N. 15th Street
SAN FRANCISCO, CALIF.....Folsom at 17th Street
SEATTLE, WASHINGTON...1520 Fourth Ave., South
ST. LOUIS, MO.....1325 Mackland Avenue
WASHINGTON, D. C.....1254 23rd St.

TWO WHEEL TRAILER

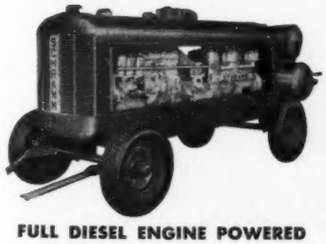


SELF-PROPELLED CRAWLER TYPE



DELUXE WITH TOOL BOXES AND HOSE REELS

SKIDDED FOR TRUCK MOUNTING



FULL DIESEL ENGINE POWERED

PORTABLE COMPRESSORS—All SCHRAMM Compressors are intended for heavy-duty, continuous service with minimum attention. They are suitable for service twenty-four hours per day and will perform such service with lowest up-keep and operating costs. The purpose of this page, therefore, is to present the standard types of SCHRAMM Compressors. Descriptions and data are necessarily brief but complete specifications and other information will be gladly furnished upon further request by any of the agencies listed above.

TWO WHEEL TRAILER TYPE MOUNTING: A model that can be very easily coupled to car or truck and hauled at towing speed.

SELF-PROPELLED CRAWLER TYPE: A complete No. 60 Crawler type compressor mechanically operated under its own power.

DELUXE WITH TOOL BOXES AND HOSE REELS: Provided with a universal trailer coupling or towing ring for connection to car or truck, for hauling at maximum towing speeds.

SKIDDED FOR TRUCK MOUNTING: Can be easily loaded on a motor truck body for temporary use or for transportation.

FULL DIESEL ENGINE POWERED: Cuts fuel costs and contributes to better performance and longer life.

STATIONARY COMPRESSORS: "V" OR FLAT BELT DRIVE: They can be had with "V" or flat belt pulley, or without pulley, with and without cooling unit, or base.

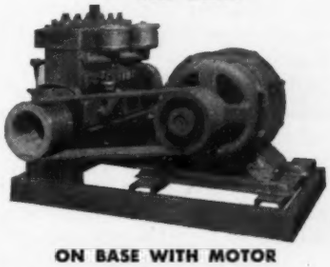
ON BASE WITH MOTOR: Belt drive assemblies are available for operation at standard speed or, at less than standard speed or where it is desirable to use a motor or engine of different speed.

DIRECT "BUILT-IN" MOTOR DRIVE: Compressor and motor are assembled rigidly and in perfect alignment, and are mounted on a substantial steel type, closed base.

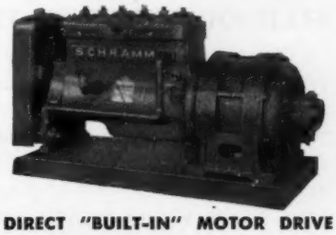
ENGINE DRIVE STATIONARY—IN-LINE—SCHRAMM Engine Driven Stationary units are made available for those applications not reached by electric power service or where gasoline, oil, distillate or diesel power units are preferred.

ENGINE BELT DRIVE ON BASE: Combinations of this type are assembled with compressor and power unit mounted on a steel frame, with "V" belt drive, a very compact and complete combination.

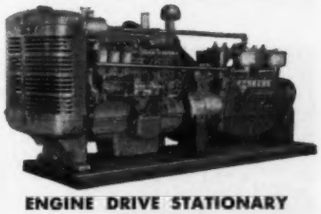
"V" BELT DRIVE



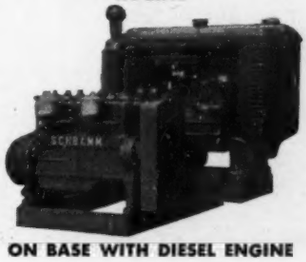
ON BASE WITH MOTOR



DIRECT "BUILT-IN" MOTOR DRIVE



ENGINE DRIVE STATIONARY IN-LINE



ON BASE WITH DIESEL ENGINE

BINS, Storage
BREECHING, Steel
CHUTES, Steel
FILTRATION PLANTS
FLUMES, Iron and Steel
GAS HOLDERS
HOPPERS, Steel
PENSTOCKS
PIPE, Riveted steel
PIPE, Welded steel

CHICAGO BRIDGE

Chicago.....2198 McCormick Bldg.
New York....3390-165 Broadway Bldg.
Cleveland.....2262 Guildhall Bldg.
Greenville .....York Street
Birmingham.....1586 North 50th St.
Tulsa.....1646 Hunt Bldg.

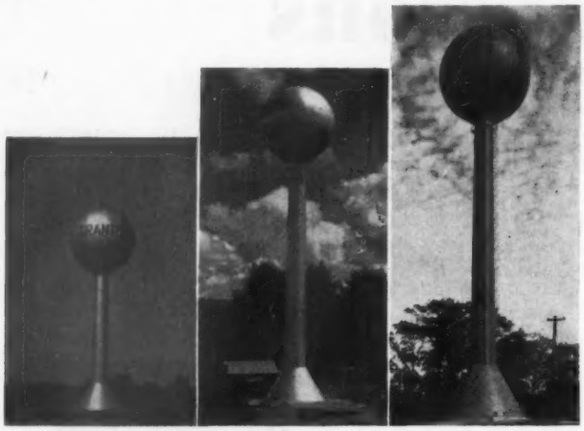
Plants in CHICAGO, ILL.; BIRMINGHAM, ALA., and GREENVILLE, PA.

FACILITIES

We are equipped to design, fabricate and erect all types of steel plate work, riveted or welded. When requesting estimating figures on tanks, state capacity, height to bottom for elevated tanks, and describe location.

INFORMATION

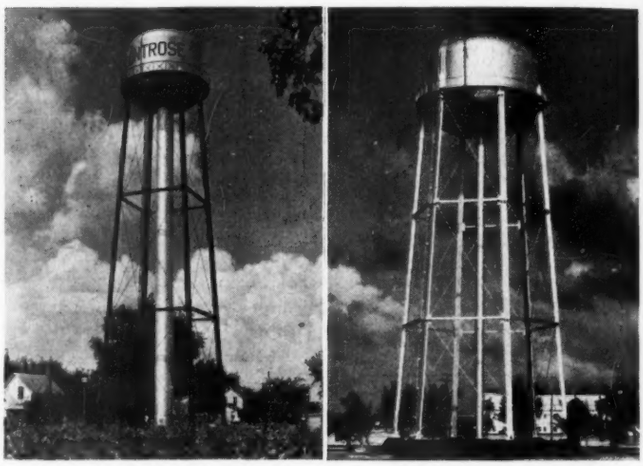
We are always glad to supply municipal officials and water-works engineers with complete information or estimating figures on any or all of our products. Address our nearest office. There is no obligation on your part.



50,000-gal., Granton, Wisconsin — *75,000-gal., Watstonbury, N. C.* — *100,000-gal., Madison, Wisconsin*

WATERSPHERES

This relatively new elevated storage tank design has attracted wide public interest because of its unusual shape. Engineers and water works operators, however, have found that Waterspheres embody highly functional construction. A single cylindrical column provides an economical means of supporting an elevated tank. The plain plate surfaces are easier to maintain than the customary structural columns. Waterspheres have been installed in over 20 municipalities in the past three years, in sizes ranging from 40,000 to 250,000 gallons.

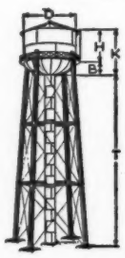


50,000-gal. Montrose, Minn. — *200,000-gal., Hollywood, Fla.*

ELLIPSOIDAL-BOTTOM ELEVATED TANKS

This type of tank is built in standard sizes as shown in the accompanying table. The tank diameter is relatively large and the depth shallow, reducing the variation in pressure between upper and lower water levels. Ellipsoidal-bottom tanks are available with two types of roofs; cone or ellipsoidal. Three typical cone roof tanks are illustrated below, and four tanks with ellipsoidal roofs and bottoms are shown above and to the right. This design provides a pleasing, modern appearance.

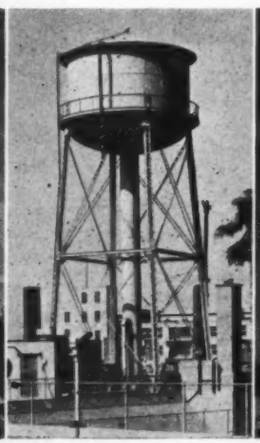
ELLIPSOIDAL-BOTTOM TANK SIZES



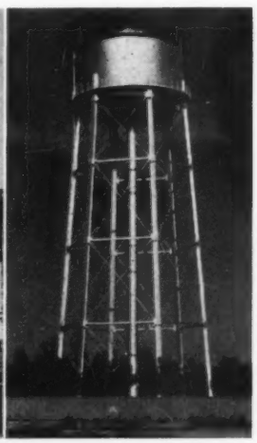
Nominal capacity, gal.	Tank dimensions			
	D	H	B	K
40,000	20'0"	13'9"	5'0"	18'9"
50,000	22'0"	14'0"	5'6"	19'6"
60,000	24'0"	14'0"	6'0"	20'0"
75,000	26'0"	15'0"	6'6"	21'6"
100,000	28'8"	16'0"	7'2"	23'2"
125,000	28'8"	21'2"	7'2"	28'4"
150,000	34'0"	16'6"	8'6"	25'0"
200,000	38'0"	17'6"	9'6"	27'0"
250,000	40'0"	20'0"	10'0"	30'0"
300,000	41'0"	23'9"	10'3"	34'0"
400,000	47'0"	23'2"	11'9"	34'11"
500,000	51'0"	24'3"	12'9"	37'0"
600,000	54'0"	26'3"	13'6"	39'9"
750,000	54'0"	32'0"	18'0"	50'0"
1,000,000	60'0"	34'0"	20'0"	54'0"
2,000,000	80'0"	35'6"	26'0"	61'6"

Height to bottom—any even foot.

50,000-gal., Mt. Palomar, Cal.



70,000-gal., Los Angeles, Cal.



250,000-gal., Brawley, Cal.

This 50-ft. diameter Hortonsphere is used to store sewage gas at 40 lbs. pressure at Sheboygan, Wis.

& IRON COMPANY

Houston.....5615 Clinton Drive
Detroit.....1551 Lafayette Bldg.
Philadelphia.....1644-1700 Walnut St.
Washington.....632 Washington Bldg.
San Francisco.....1083 Rialto Bldg.
Havana.....402 Edificio Abreu

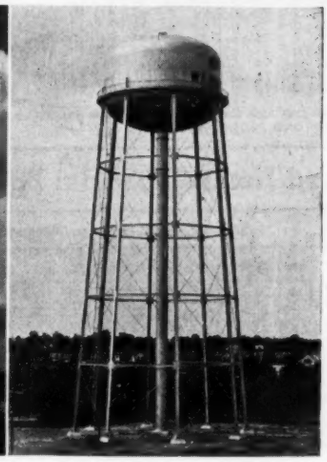
In Canada: HORTON STEEL WORKS, LIMITED, Fort Erie, Ontario

PRESSURE VESSELS, Welded
RESERVOIRS, Steel
RECEIVERS, Air
SMOKE STACKS
STANDPIPES

STEEL PLATE WORK
TANKS, Elevated Steel
TANKS, Storage
TANKS, Surge
TANKS, Washwater

Three large capacity Horton radial-cone bottom elevated tanks are illustrated at the right. Capacities and locations are as follows (left to right): 500,000-gal., Holland, Mich.; 1,000,000-gal., Tucson, Ariz.; and a 1,500,000-gal. "Colonial" design unit installed at Hammond, Ind.

300,000-gal., Pleasant Hill, Md.



500,000-gal., Bristol, Penna.

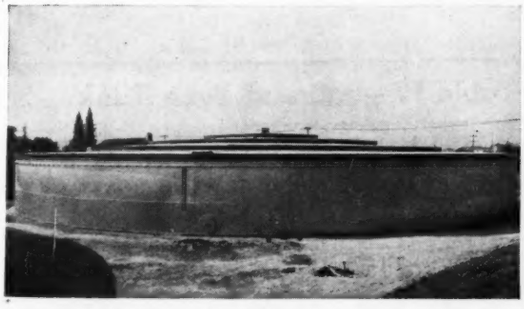
RADIAL-CONE BOTTOM TANKS

The radial-cone bottom design was developed to permit the construction of large capacity tanks with a small range in head. (See installations shown above at Holland, Mich.; Tucson, Ariz.; and Hammond, Ind.) Radial-cone tanks are of sound structural design. They present a pleasing appearance. Construction details such as tower bracing, hand railing, etc., may be varied to secure the desired architectural effect. The accompanying table indicates the proportions for the various capacities.

STANDARD RADIAL-CONE SIZES

Capacity (Gallons)	Diameter of Tank	Depth of Tank
500,000	61′	25′
750,000	76′ 8″	25′
1,000,000	87′	25′
1,500,000	106′	25′
2,000,000	122′	25′

A booklet is available, showing numerous radial-cone bottom installations. Copies will be sent on request.



Left: One of two 2,300,000-gal. all-welded steel water reservoirs installed at Alhambra, Calif.

RESERVOIRS

Where natural elevations are available, flat-bottom steel reservoirs provide efficient gravity pressure. They are built in standard sizes or special designs to meet your requirements, of riveted or welded construction, with or without roofs.

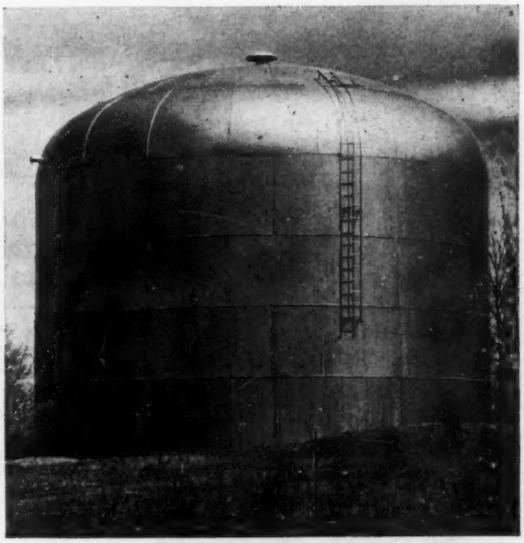
100,000-gal. wash water tank at Michigan City, Ind.

WASHWATER TANKS

We build ellipsoidal, radial-cone or special shaped tanks to give exactly the capacity, head, and pressure variation required for washing filters.

SEWAGE GAS HOLDERS

When gas from digesters at sewage disposal plants is utilized, excess quantities produced during peak periods can be stored advantageously under pressure in a Hortonsphere for use during off-peak periods. Hortonspheres are relatively small in size and pleasing in appearance. We also build conventional lift-type gas holders.



300,000-gal., ellipsoidal-roof, flat-bottom water storage tank at Eden, New York.

PITTSBURGH-DES MOINES STEEL CO.

Tanks—Plate Fabrication—Structural Steel

Sales Offices at: 3418 NEVILLE ISLAND, PITTSBURGH, PA. . . . 919 TUTTLE STREET, DES MOINES, IOWA
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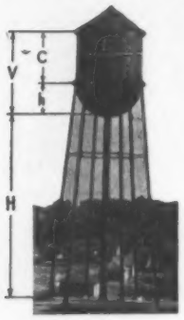
1223 PRAETORIAN BLDG., DALLAS, TEX. . . . 625 RIALTO BLDG., SAN FRANCISCO, CALIF.

In these tables we have compiled—in compact but complete form—data on steel reservoirs and on the various types of elevated steel tanks. For information as to the application of these various types of tanks, for designs, for specifications, or for estimates—write our nearest office.

Table I—Pittsburgh-Des Moines Standard Hemispherical Bottom Elevated Tanks



Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity											
				ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
5,000	9	10 0	11 3	11 3	18 9	31 9	38 3	51 9	58 9	72 9	79 9	93 9	100 9	.....	.....
10,000	13	5 11	11 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
15,000	13	10 11	16 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
20,000	13	15 11	21 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
25,000	15	14 7	19 11	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....
30,000	15	18 5	23 9	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....
40,000	17	18 5	25 1	46 8	.....	.....	75 0	.....	96 3	100 0	.....	125 0	.....	.....	.....
50,000	19	17 7	25 7	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
60,000	19	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
75,000	21	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
100,000	24	22 6	31 0	.....	50 0	63 1	75 0	79 7	91 6	100 0	113 1	116 6	125 0	141 6	153 4
150,000	28	24 2	34 7	46 6	54 10	63 2	75 0	83 4	91 8	100 0	111 10	120 2	128 6	140 3	148 7
200,000	32	23 4	36 1	45 9	54 1	62 5	75 0	83 4	91 8	100 0	112 7	120 11	129 3	141 10	150 2
250,000	32	31 4	45 4	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 8	151 0
300,000	36	28 4	42 5	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 9	151 1
400,000	40	30 0	46 6	44 6	52 10	61 2	75 0	83 4	91 8	100 0	113 10	122 2	130 6	138 10	152 8
500,000	44	29 9	49 2	43 6	51 10	60 2	75 0	83 4	91 8	100 0	114 10	123 2	131 6	139 10	154 7
600,000	44	38 6	58 2	} Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.											
750,000	50	34 9	57 5												
1,000,000	50	52 0	73 9												

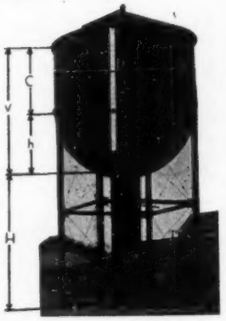
Table II—Pittsburgh-Des Moines Standard Hemi-ellipsoidal Bottom Elevated Tanks

Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity											
				ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
25,000	17	11 9	15 5	46 4	51 8	71 4	75 0	.....	96 4	100 0	.....	126 8	...	.....	.....
30,000	17	14 7	18 6	46 1	51 5	71 1	75 0	.....	96 1	100 0	.....	126 5	.....	.....	.....
40,000	21	11 3	16 9	47 5	.....	.....	75 0	.....	97 5	100 0	.....	126 2	.....	.....	.....
50,000	22	13 2	19 0	.....	57 2	65 6	75 0	85 6	93 10	100 0	113 10	122 2	130 6	142 2	150 6
60,000	24	12 10	19 4	.....	56 6	64 10	75 0	84 8	93 2	100 0	113 2	121 6	129 10	141 6	149 10
75,000	26	13 6	20 8	.....	55 10	64 2	75 0	84 2	92 6	100 0	112 6	120 10	129 2	140 10	149 2
100,000	28	16 2	23 2	.....	51 6	64 7	75 0	81 1	93 0	100 0	114 7	118 0	126 6	143 0	154 10
150,000	34	14 10	25 0	46 9	55 1	63 5	75 0	83 7	91 11	100 0	112 1	120 5	128 9	140 6	148 10
200,000	38	15 5	27 0	46 11	55 3	63 7	75 0	84 6	92 0	100 0	113 9	122 1	130 5	143 0	151 4
250,000	40	18 1	30 0	47 5	55 9	64 1	75 0	85 5	93 9	100 0	115 1	123 5	131 9	140 1	153 1
300,000	40	23 11	34 0	49 5	57 8	66 0	75 0	87 4	95 8	100 0	117 0	125 4	133 8	142 0	155 0
400,000	46	22 9	34 11	48 10	57 2	65 6	75 0	87 8	96 0	100 0	118 2	126 6	134 10	143 2	157 0
500,000	50	23 9	37 0	49 8	58 0	66 4	75 0	81 2	89 6	100 0	112 8	121 1	129 4	146 0	152 5
600,000	55	21 9	39 7	} Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.											
750,000	60	22 4	42 4												
1,000,000	60	35 0	54 0												
1,000,000	65	26 1	47 7												
1,250,000	79	17 4	43 4												
1,500,000	70	37 8	60 0												
1,500,000	79	24 0	50 0												
2,000,000	90' 3"	22 6	50 0												

Table III—Double Ellipsoidal Tanks

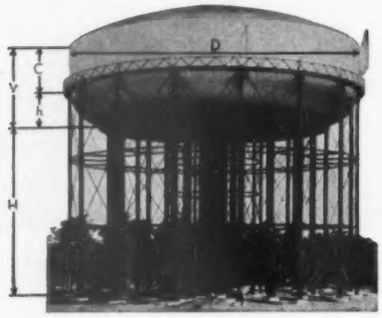
Capacity in U.S. Gallons	D	B	C	T	V	H
50,000	22'-0"	5'-10"	9'-4"	4'-4"	19'-6"	Built to Order
75,000	26'-0"	7'-0"	9'-0"	5'-0"	21'-0"	
100,000	28'-0"	7'-0"	11'-1"	5'-7"	23'-8"	
150,000	34'-0"	10'-0"	8'-8"	6'-10"	25'-6"	
200,000	36'-0"	9'-0"	12'-11"	6'-9"	28'-8"	
250,000	40'-0"	10'-4"	11'-7"	7'-6"	29'-5"	
275,000	40'-0"	11'-11"	13'-9"	7'-6"	33'-2"	
300,000	40'-0"	8'-7"	17'-11"	7'-6"	34'-0"	
350,000	44'-0"	14'-8"	13'-10"	8'-0"	36'-6"	
400,000	46'-0"	12'-2"	14'-9"	8'-8"	35'-7"	
500,000	50'-0"	15'-0"	14'-6"	9'-8"	39'-2"	
600,000	55'-0"	14'-4"	14'-0"	10'-0"	38'-4"	
750,000	60'-0"	15'-11"	12'-7"	11'-6"	40'-0"	
1,000,000	65'-0"	21'-8"	15'-9"	11'-0"	48'-5"	

Table IV—Railroad Type Tanks



Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft.	C in.	V ft.	V in.	H
20,000	15	10	9	16	2	Any height from 15' 0" to 40' 0" in multiples of 5' 0"
25,000	15	14	7	19	11	
30,000	17	12	7	19	0	
40,000	19	13	1	20	6	
50,000	21	13	1	21	1	
60,000	24	10	1	20	3	
75,000	24	15	1	23	10	
100,000	28	13	5	23	7	
150,000	28	14	2	24	7	
200,000	36	15	1	29	2	
250,000	38	17	3	33	3	
300,000	38	23	11	38	3	

Table V—Toroidal Bottom Tanks



Capacity in U. S. Gallons	Tank Diameter (D) when h = 10' 0" and V = 20' 0" ft.	in.	V = 25' 0" ft.	in.	V = 30' 0" ft.	in.	V = 35' 0" ft.	in.	H
750,000	82	0	73	2	66	8	61	8	Built to Order
1,000,000	94	5	84	3	76	9	71	0	
1,250,000	105	4	94	0	85	8	79	2	
1,500,000	115	2	102	9	93	9	86	8	
2,000,000	132	8	118	5	108	0	99	11	
2,500,000	148	0	132	3	120	7	111	6	
3,000,000	162	0	144	8	131	11	122	1	
4,000,000	186	8	166	9	152	2	140	9	
5,000,000	208	6	186	3	169	11	157	3	

Table VI—Steel Reservoirs

Capacity in U.S. Gallons	Diameter ft.	Height ft.	Height in.
50,000	20	21	6
60,000	22	21	6
75,000	24	22	6
100,000	26	25	6
150,000	30	28	9
200,000	34	29	9
250,000	38	29	9
300,000	42	29	3
400,000	46	32	6
500,000	50	34	6
750,000	60	35	9
1,000,000	70	35	0
1,500,000	80	40	3
2,000,000	95	38	3
2,500,000	110	35	6
3,000,000	120	35	9
4,000,000	130	40	9

ELEVATED STORAGE

The Value of Elevated Tanks on Water Supply Systems

By CHARLES BROSSMAN

Late Consulting Engineer, Indianapolis, Ind.*

In many cities the advantages of elevated water storage has been recognized, usually with considerable return on the investment.

On closed water systems without some form of storage facilities, where centrifugal pumps are in service, the pumps are usually installed large enough to take care of peak loads. It is quite evident that, with a pump available to take care of such peak loads, on the lighter loads (especially at night), the pump drops off greatly in efficiency, as does the motor. Such day in and day out waste of power mounts to an appreciable sum as time passes, until losses overbalance the costs of providing storage on the system —in instances many times over.

For instance: Assume a modern pump operating at full load efficiency of 70%, and motor at 90%. The unit will give a combined efficiency of 63%. This pump on the lighter loads, with a drop in efficiency of 50%, and the motor at 80%, gives a combined efficiency of only 40%, a difference between the two of 23 points.

It is readily realized that with such a condition recurring daily, the power consumption may be surprisingly increased for the year. Not alone such current waste, but if power is being purchased with a maximum demand charge on the motor size the rate will be increased due to this factor, for the reason that the pump motor must be large enough to take care of the peak load. On the other hand, an elevated tank will allow more uniform pumping, the pump and motor size can be reduced, thereby reducing the costly demand factor.

Another very evident disadvantage is that pressure is lost immediately whenever pump service is interrupted for any of several possible reasons. In case of fire such is disastrous. In any case, the public served is paying a penalty in insurance rates where pressure storage is not available on the system.

Furthermore, another advantage from elevated storage is that any pump on the line can be used at its maximum output, and with a correspondingly maximum efficiency. Pumps, therefore, can be purchased for use with elevated tank service over their maximum range of efficiency, with assurance that such efficiency can be realized in every day operation.

Another advantage is uniform pressure. With an elevated tank, automatic regulating control is available, whereby the tank variation in head may be kept within a few feet, thereby giving absolutely uniform pressures under all conditions of draft on the system. Particularly advantageous are elevated tanks in outlying districts, to reduce pumping costs and render better service pressures and flow. It is hardly necessary to indicate that more water will be used, in consequence, and a higher income enjoyed by the water utility.

In considering the values of elevated tanks for water storage it is apparent that there are a number of advantages.

Power Saving Case Records

The first advantage, that of saving in power cost, is the most appealing and in practically all cases a considerable saving in power will result. As a concrete example we may take the experience of a small plant in a town of 1,100 with which the writer is very familiar.

The Town of Albion, Indiana, had a water consumption of approximately 50,000 gallons per day. In this case an elevated tank was installed, the total cost of the tank being approximately $7,200.00. The power used before installing this tank, on the closed system, was approximately 1 KWH for 530 gallons; after the tank was installed, pumping was approximately 1 KWH for 1,050 gallons. This proved a spectacular attainment of cutting power consumption in half, but there are other Albions scattered over the country.

In this particular case, the tank will be paid for in less than 15 years by the saving in power bills alone. If the rate of consumption increases the time will be shorter, of course.

Here is a point of considerable interest in this case. Albion has its own generating plant, and the total cost of power is considered at 3c per KWH, including all costs. A careful check on all costs and power used still indicates the investment well justified. One reason is found in the fact that fire protection is now supplied with the small 200 G.P.M. pump and the large steam fire pump is no longer maintained as a ready to serve unit with fire in the boiler. Steam, however, can be had from the municipal power plant in case of necessity, and the pump is still available.

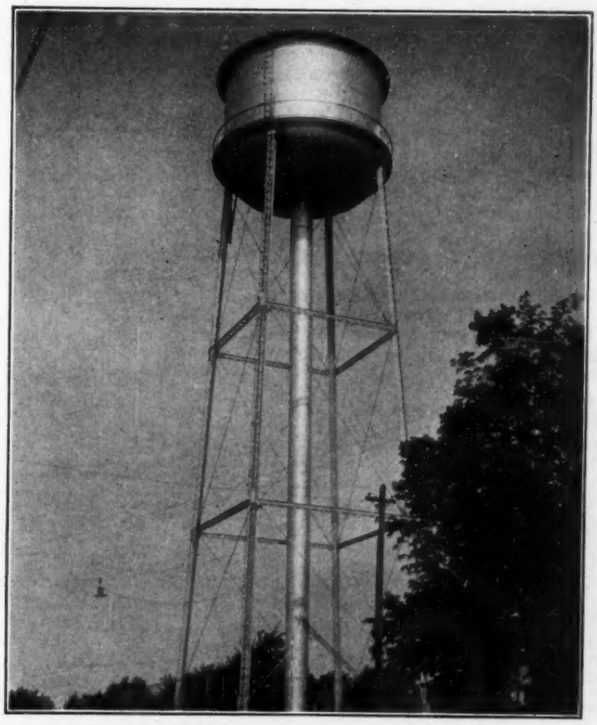
Another example is found in the City of Goshen, Indiana, where there has been installed a 500,000 gallon tank. The old plant was steam driven. About six years ago, the city installed a modern Diesel lighting plant, but only two of their deep well pumps were electrified at that time. The boilers had to be kept going at all times in the old steam plant, in order to have available suitable fire protection. In this case, a P.W.A. loan made it possible for Goshen to electrify its water works system. The city now has eight electric driven deep well pumps, and a new half million gallon tank. The loan by P.W.A. was negotiated on the basis of anticipated savings resulting from abandonment of the steam plant.

The cost of pumping for the old system on which boilers had to be kept up at all times, was given at approximately 8.3c per thousand gallons, which of course, was high, but the equipment was old, and used air lift pumps and double pumping, except for the two electric driven pumps.

It is estimated that the actual electrical pumping cost would be in the neighborhood of 1.2c per thousand gallons, and total cost at 2.2c per thousand. To take advantage of the potential saving (about 6c per thousand) an elevated tank had to be installed.

The old standpipe was not adequate for the demands, as the upper portion of this standpipe did not store very much water. The new elevated tank, of one-half million gallons, was installed some distance from the plant and on the opposite side of the city.

The entire pumping equipment is automatically controlled, there



The 50,000 Gal. Tank of Albion, Ind.
Will pay for itself in less than fifteen years.

* Excerpts from a paper written by Mr. Brossman shortly before his death. It was presented before the Indiana Section of A.W.W.A.,

being two automatically controlled pumps at the tank site (about 1.5 miles from the main station), and six automatically controlled deep well pumps at the main station, each pump having a capacity of 500 G.P.M. Any pump can be manually started or stopped by push button control from the main plant.

Results at Goshen

Merle J. Miller, Superintendent and Manager of the Goshen plant, has made it possible for me to take the following from his report on the Goshen betterments.

"With a stand-pipe of the small capacity that we had previous to the erection of our new elevated tank, our water circuits were only fairly stable, but since the additional storage capacity has been added to our system, it has made a wonderful change in our water pressure charts as there is more cushion and no surge anywhere along the line. A number of charts taken at the elevated tank location have been absolutely perfect from the standpoint of surges or variation in pressure. We found before, especially with the steam pumping equipment, that we could detect each pulsation of the steam pump, as our standpipe capacity, at that time, was not enough to cushion the whole system properly. Comparing the old system as against the new system for uniform pressure, there is a vast difference. From the new system, if given any attention at all, we get a chart of uniform pressure, with as little variation as one pound.

"We also find a marked difference in the circulation of the water in districts where we had frequent complaints during the warm summer months against the warm stagnant water."

From the foregoing, it will be seen that in any plant that does not have an elevated tank, or if they have a standpipe of very small capacity, with very little water available in the upper section, the modern type of elevated tank, with all of the storage at the proper level, will almost invariably result in a financial saving, as well as give the other advantages which accrue to it.

One of the Two 1,500,000 *Gal. Tanks of Indianapolis*
A leafy green and silver structure which constitutes a study in "neighborhood-treatment" of water towers.

Concerning Fire Protection Requirements

The relation of the elevated tank to fire protection is one of the important factors that should not be lost sight of. Modern elevated tanks, as compared to old standpipes, are much different for the available capacity for fire fighting facilities, as credit for water in a standpipe is only allowed for the top sections. Modern tanks, as now designed, keeps the water level to within a few feet variation, dependent more or less upon type of regulating control on the electric pumps.

Fire flows should not be confused with the total daily flow or capacity. For instance: if a town has a total available supply and storage based on a 24-hour period the fire flow will usually be based on a 5-hour flow for communities of 2,500 and less, which means that they will need 4.8 times the average consumption capacity as storage capacity for fire. For cities above 2,500 the multiplier will be 2.4 times for fire storage, as against consumer use storage. Such is based on a requirement of capacity for not less than a 10-hour period of continuous fire flow.

The fire flow requirements for average cities are given by the Underwriters, as follows:

Population	Required Flow (G.P.M.)
1,000	1,000*
2,000	1,500*
4,000	2,000
6,000	2,500
10,000	3,000
13,000	3,500
17,000	4,000
22,000	4,500
28,000	5,000
40,000	6,000
60,000	7,000
80,000	8,000
100,000	9,000

* For 5 consecutive hours; all higher flows for 10 consecutive hours.

Therefore, in selecting the tank the fire flow for the period required, according to population, is the primary consideration. To this must be added the domestic consumption.

This amount indicated is then balanced against the available low lift capacity of the pumps, such as wells or filters, also the ground storage capacity. The total low lift and ground storage capacity is then determined.

The second step is to figure the high lift pump capacity and the elevated storage capacity.

After these two quantities are known, they are compared to the required fire flow and domestic flow over the 5 or 10-hour period, as the case may be. This will then give the ideal condition in installed pumping capacity and tank size.

In case these conditions are not met, if there is a deficiency in pumping capacity or storage on either the low lift and ground storage or high lift and elevated storage, this deficiency will be taken into account in the making of rates.

It should be clearly kept in mind that the total 24 hours available capacity is not what is considered by the Underwriters. They base the capacity wholly on the fire flows listed for the period of hours noted.

Concerning Tower Heights

The matter of pressure from elevated tanks should not be lost sight of, as various pressures are required for certain types of buildings, according to the size town and construction therein.

One of the outstanding tank installations in this country, is that installed by the Indianapolis Water Company.

This large tank is located in the eastern section of Indianapolis, which is approximately 100 feet higher than their main pumping station. With this long line of pipe, and the ensuing friction losses, pressures were previously very low in this district. It was decided, after considerable study of ground as elevated storage, to erect an elevated tank with 1,500,000 gallons capacity to serve the approximately 64,000 people in this district. This tank has resulted in great improvement in pressure and supply, with an ensuing satisfaction to the water consumers.

This tank is the largest one in the state of Indiana on a public water supply, the tank being 72 feet to the bottom, and with this large capacity, having a range of only 25 feet between the upper and lower water levels. As the result of benefits noted the Water Company is undertaking a tank of like capacity in another section.*

In conclusion, I would state that there are many plants on which a study of water storage as well as pump efficiencies connected therewith, would result in a marked saving in the operation of such plants.

* Since the writing of this paper the second tank has been erected and placed in service. This installation, with the new Cathodic-protection system for safeguarding its interior against corrosion, is fully described in the November, 1939 issue of "WATER WORKS AND SEWERAGE."

R. D. COLE MANUFACTURING CO.

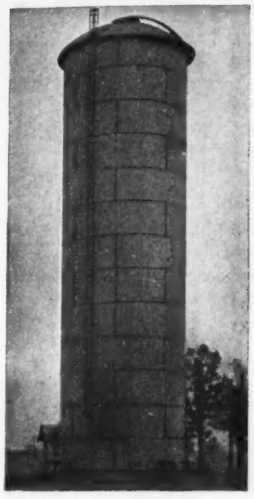
Est. 1854

Tanks, Towers, and Steel Plate Work
NEWNAN, GA.

5,000 TO 2,000,000-GALLON WATER TANKS

All shapes and sizes—The R. D. COLE MANUFACTURING CO. has developed a complete line of elevated steel tanks for water supply, both for domestic service and sprinkler requirements, ranging in capacity from 5,000 to 2,000,000 gallons.

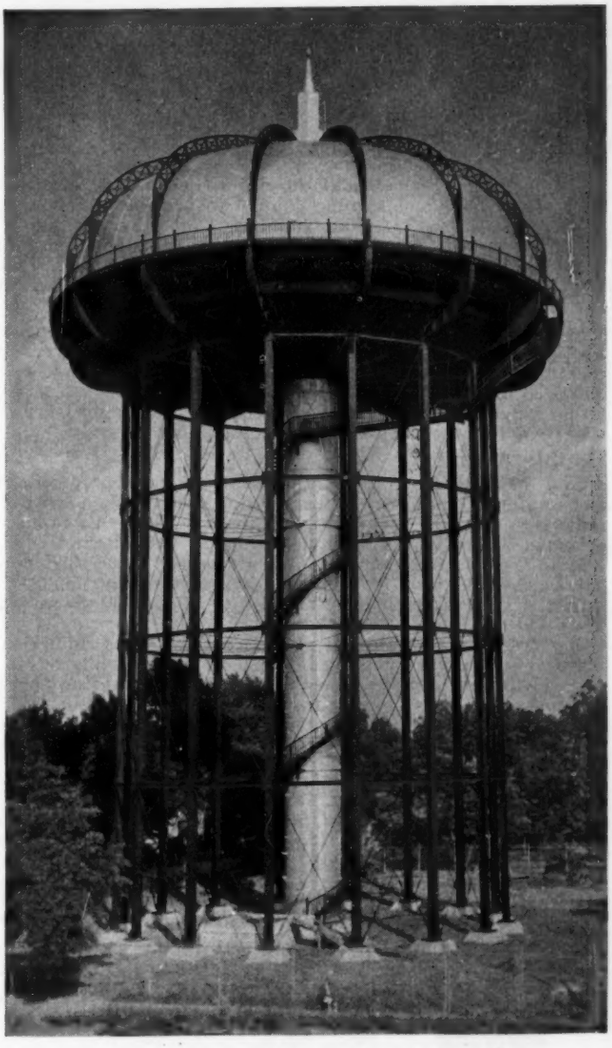
The designs include the standard Hemispherical Self-supporting Bottom, the "Cole Ovaloid," Standpipe and many individual styles involving architectural treatment to satisfy local conditions, or to provide special shapes for advertising purposes.



STORAGE TANKS

Pressure tanks for storage of gas from digesters at sewage disposal plants so that excess output at peak loads can be used during off-peak periods. Chemical storage tanks, hot water storage tanks, tanks for bulk storage of oils and gas.

Designs Available for Any Service



1,000,000-Gallon "Cole-Shallow Depth" Tank

CONSTRUCTION FACILITIES

Fabricated Steel Plate—The R. D. COLE MANUFACTURING CO. has a fully equipped plant for the fabrication of riveted or welded steel plate. In addition to the construction of its regular line of horizontal return tubular boilers, oil storage tanks, tubular heaters, etc., the company is prepared to construct special tanks and apparatus of any specified metal plate.

Alloys and Lining for Processing Apparatus—The facilities and experience of the company enable it to fabricate special apparatus of all kinds for the processing industry using alloy steel plates, stainless steel, nickel-clad steel, etc., or linings such as lead, tin, nickel or Monel.

ROSS VALVE MFG. CO., INC.

TROY, NEW YORK.

AUTOMATIC CONTROL & PRESSURE REGULATING VALVES

***For* Water Works and Fire Departments**

For accurate service, the automatic control and pressure regulating valves must be right as to type and size for the service required. Our W. R. Type, cast iron, bronze mounted valves in sizes from 4" to 30" are guaranteed for the services for which they are designed.

Altitude Valves

Single Acting

Model 40 AWR—semi-throttling hydraulic control to prevent overflow of tank, standpipe or reservoir or to maintain a positive adjustable head for washing and filtering operations. Pilot adjustment range—4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Model 30 AWR—wide open or closed hydraulic control to prevent overflow of tank, standpipe or reservoir. Pilot adjustment range 4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Other single acting altitude valves combine back pressure or relief valve and pressure reducing functions.

Double Acting

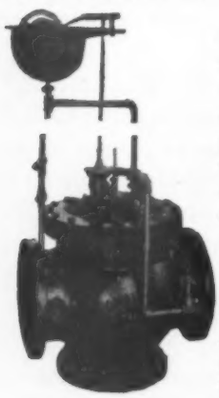
Model 40 DAWR—to prevent overflow in tank or reservoir and to allow return flow to distribution system when head on tank side is three inches higher than head of distribution system. These valves may be equipped with Remote Hydraulic and Electric Control. When required the return flow can be delayed for a predetermined pressure drop in distribution. Pilot adjustment range—4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Other double acting altitude valves combine many additional features to prevent dumping of tank, to retain supply on off-peak loads and to make available maximum storage for peak load periods. Also a semi-throttling model for gradual closing of feed line and for maintenance of adjusted pressure on the distribution side. Can be equipped with secondary pilot to close valve if break occurs in distribution system.

Surge — Relief — Back-pressure Valves

Model 50 RWR—Single Pilot, Electric and Hydraulic Control—for protection against excessive pressures in distribution systems, supply lines and pump discharge lines. Installed in discharge line of deep well pump, provides constant back pressure to prevent overdrafting of the well. Pressure range on pilot—10 to 60 lbs., 20 to 150 lbs., 125 to 250 lbs.

Float Valve or Level Controller



Model 50 FWR—External Pilot Operated—to control main valve so that main stem operates wide open or closed. Pilot valve wastes to atmosphere contents only of operating chamber each time valve stem rises to open position. Maximum inlet pressure, 175 lbs.

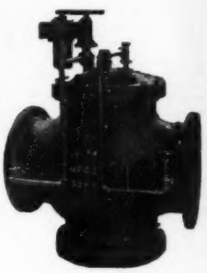
Model 40 FWR—External Pilot Operated, Semi-throttling—for gradual closing of valve during last three inches before overflow.

Reducing and Regulating Valves

Model 40 WR—Single Pilot, Hydraulic Control—to maintain constant desired discharge pressure regardless of rate of flow or pressure on upstream side of valve. As a pressure reducing valve, operates to:

1. Control and regulate pressures in gravity and pumping systems
2. Regulate flow between reservoirs and zones of different pressures
3. Regulate fire flows between zones of unequal pressures
4. Regulate pressures in filter wash lines and aerator nozzles.

Valves operate without waste of water to atmosphere and will not induce surge. Can be equipped with dual pilot to permit changing from one pressure to another by mere operation of a three-way cock for systems operating under different day and night pressures. Valves may be supplied with right-angle body. Pressure range outlet—10 to 60 lbs., 20 to 150 lbs., 125 to 250 lbs.



Model 40 WR—Single Pilot, Electric Remote Control—motor driven, geared to pilot adjusting tail screw, made with limit stops to prevent over-travel, and operated by push button switch.

Pressure Reducing and Reverse Flow Valves

Model 50 WR—Single Pilot, Hydraulic Control—for installation at dividing line between two zones to reduce pressure from higher zone, to function as a sleeping valve, discharging into low zone at a time of excessive draft, to permit flow from low to high zone when excessive draft in high zone reduces its pressure below that of the low zone as in case of fire. Pressure range outlet—15 to 60 lbs., 20 to 150 lbs. This valve may be equipped with dual pilot control to permit greater ranges in pilot control and to provide the assurance which goes with duplication and stand-by units.

FIRE DEPARTMENT SPECIALTIES

Portable Fire Hydrant Head for Pressure Reduction—Internal Pilot Operated—for attachment to high pressure main; carried on apparatus to fire, one man can attach (110 lbs. weight) in 18 to 30 seconds, four 2½" hose connections delivering independently from shutoff to full pressure and a fifth connection 2½" to 3" delivering full pressure.

Hose Valves for Pressure Reduction
Fire Engine Relief Valves

All Ross Valves Repaired in Line: Internal Packing Replaced Through Top of Valves.

MAINTENANCE OF TANKS AND STANDPIPES

By WILLIAM S. STAUB, Engineer
West Virginia Water Service Co., Charleston, W. Va.

THE elevated tank or standpipe is one of the most costly single items amongst above-ground structures of a water system. Yet as a general rule they receive the least attention and very little is done in the way of yearly maintenance to keep the valuable units in first class condition. Tanks are generally located in inaccessible or out of the way places and the public is not afforded the opportunity to offer criticism of their appearance and frequently, deteriorated condition. The condition of an isolated tank will generally provide a good barometer as to the condition of the remainder of any given water supply system. A well maintained tank represents to me that other structures and equipment comprising the system will be in good condition.

A tank is located in a distribution system to

1. Provide for peak demand.
2. Provide for uniform pumping head.

Peak demand may be subdivided into domestic, commercial, industrial and fire-demand. By providing some several hours of storage, we are able to operate with filtration plants, pumping equipment, etc., much smaller output capacities than otherwise. With adequate storage, properly placed in respect to the system design, conservative uniform output may be used which will make possible the performance and efficiency of pumping equipment at maximum economy and insured service expectancy.

Some Basic Considerations

Many maintenance worries may be eliminated by considering basic principles when plans are being drawn preliminary to tank erection. Proper foundations, anchorage, maintenance, accessories, painting and rigid inspection will prevent many abnormal maintenance worries.

Sufficient foundation should be provided that unequal settling and abnormal stresses in the tank may be eliminated. Heat, cold, wind, high and low water levels, all cause stresses in the tank that may tax the physical qualities of the material, without introducing those that may be prevented. The writer's company has built five standpipes at Charleston during the last two years. The largest of these was a riveted steel tank 100 feet in diameter, 52 feet high, with a capacity of 3,000,000 gallons.

Foundations and Bottom Important

All of these tanks have been constructed on foundations consisting of reinforced concrete rings. The foundations of these rings have been placed on rock and sufficiently anchored. The interior of the rings, upon which will rest the bottom plate of the tanks, have been built up of thoroughly compacted earth, capped with a 10 inch gravel mat and in turn capped with a 2 inch sand mat. The sand mat is always permitted to rise about 1 inch above the top level of the ring. This allows cushioned uniform settling when the weight of the full tank is superimposed. At the bottom of the gravel mat we have placed a grid system of 1 inch and 2 inch perforated galvanized pipe. Short nipples of this grid project through the concrete ring and are capped. After the tank has been constructed the voids in the sand and gravel are filled with oil through this grid system. In this manner it is possible to keep protective oil in contact with the bottom of the tank instead of water produced by sweating, rain or seepage, corrosively oxygen saturated

The bottom plates of the tanks have been welded and we specify that an asbestos strip 6 inches wide be placed at each lap. Over this strip and the entire bottom of tank "No-Oxide" [A] Special or a similar substance is placed. The asbestos strip prevents the burning of the "No-Oxide" coating when the plates are being welded.

Sufficient anchorage is always used so that there will be no danger of the tank being overturned by a wind when emptied. In the event a tank is emptied, and there is any question as to sufficient anchorage provided, it is always a show of wisdom to guy the tank first.

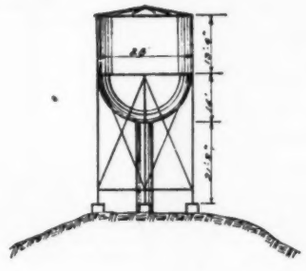
Miscellaneous Items

There should be provided on every tank an overflow of sufficient size to carry the water away in the event the control system should fail. The overflow line should be designed to preclude chokage or air binding. Landslides and damaged property are expensive items and there should be no risks in the design and maintenance of adequate overflow facilities.

Another very inexpensive item to be considered is a painting trolley. Rigging for cleaning and painting will be very simple with this adjunct, provided, and the work can be done cheaper and safer. A trolley will save many dollars in later years.

In the shell of the tank, near the bottom, there should be a manhole of sufficient size to permit all material and equipment to

CONSTRUCTED 1924
BY Pitt. D. M. Steel Co.
CAPACITY 100 000 GALLONS



YEAR	EXTERIOR	INTERIOR	FOUNDATIONS	RISER
1930				
1931				
1932				
1933	Good	Good	Good	Good
1934	Good	Good	Good	Good
1935	Fair	Good	Good	Fair
1936	Fair	Good	Good	Fair
1937	Fair	Good	Good	Fair
1938	Painted	Good	Good	Painted
1939				
1940				
1941				
1942				
1943				
1944				
1945				
1946				
1947				
1948				
1949				
1950				

WEST VIRGINIA WATER SERVICE CO.
CHARLESTON
LOUDON HEIGHTS TANK

Specimen, Inspection Record and Sketch Sheet

pass when there is to be any cleaning or painting on the interior.

[It may also serve to save the lives of workmen as proved the case in a situation when a freshly coated tank caught fire in 1938.—Ed.]

An outside ladder should be provided so that the height of water in the tank may be checked, and the interior inspected at any time. Also, to permit the paint trolleys to be moved when there is work being done on the tank. If the tank is high there should be a safety-cage around the ladder and some provision at the bottom to prevent its becoming an attraction nuisance.

Cleaning and Coating or Painting

The item of painting is last but surely not least important. This item may cause a great deal of discussion. Different waters will act differently on the interior of tanks and varied conditions of atmosphere will affect the exterior differently. For a number of years we have used on our tanks prime coats of red lead and a sealer coat of aluminum paint. The results have been very satisfactory, but there are numerous coatings and paint producers who claim better results with other substances. Test specimens and time alone will prove the superiority of such substances. The 3,000,000 gallon tank previously mentioned in this paper was a very expensive tank and due consideration was given to the conditioning of the plates and to the painting. For your information the following section taken from the specifications will show the decision on the painting.

"The plates are to receive one shop coat of red-lead and the water side of all plates two field coats of red-lead of the following mix:

Paste red lead	100 lbs.
Boiled linseed oil	1½ gal.
Fine powdered litharge	8 lbs.
Turpentine	¾ gal.

The outside of plates are to receive one shop cooat of red-lead and one field coat of red-lead of a mix of the following proportions:

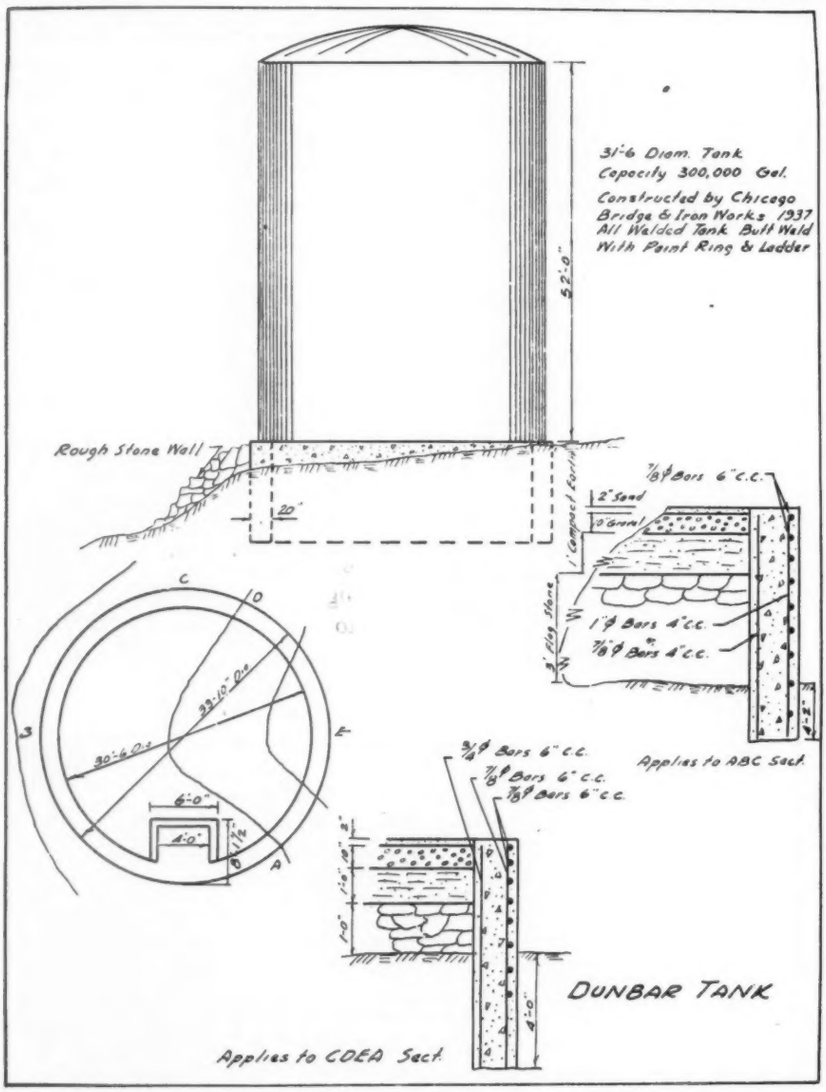
Paste red lead	100 lbs.
Raw linseed oil	2⅛ gal.
Drier	1 qt.
Turpentine	1 qt.

The outside of plates are to receive one shop coat of red-lead Aluminum Graphite Paint."

We believe that this is the best paint job ever applied on any of our tanks and we are using these specifications on all new construction and also on maintenance jobs.

An Inspection System

At the present time we have 6 elevated steel tanks and 13 steel standpipes at our different plants throughout West Virginia. We use an inspection and report system that will enable us to keep a close check on the condition of these tanks. From the annual report of the plant superintendent on the forms provided, and from our personal inspection we provide in the budget for any maintenance that the tanks must receive. By this method it is also possible to keep a record showing the results obtained by the previous protection applied.



Specimen, Design Sketch Which Is Kept in Tank Binder with Inspection Record Sheets

Cleaning Practice

The cleaning of a tank is by far the most costly item in tank maintenance. It is worse than useless to paint an improperly cleaned tank. It has been our policy to secure a good clean metal before any primer is applied. There has been some difficulty and expense in doing so, but our experience shows that an improperly cleaned surface will blister and peel within a year after paint is applied. We are using at the present time an Aurand cleaning tool, operating on compressed air, that has given fine results. This tool weighs but 7½ pounds and is not burdensome to those using it. It is composed of a rotary cylinder on which circular blades are loosely fit. These blades are replaceable, and it is also possible to replace these scraping blades which wire brush wheels. The tool can also be purchased to operate electrically. For further information the reader may write to Aurmand Mfg. & Equipment Co., Box 83, S. Y., Cincinnati, Ohio.

The most expensive single item in cleaning is the tower legs on the elevated tanks. Due to the fact that the intricate lattice bars are spaced so close that it is difficult to clean properly with any form of tool. To properly clean a 35 foot tower leg costs approximately $45.00. With four or six legs, the cleaning cost of an elevated tank is unreasonably high. If we were to construct an elevated tank we would investigate thoroughly the possibility of using a single column for the legs. If this were not possible a plate would be substituted for the lattice bars of a built up member. The cost of the additional weight of steel would certainly be classed as a credit to maintenance.

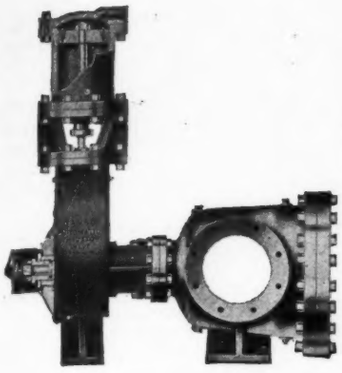
Accompanying this paper are specimen record sheets of tanks, such as we use.

I recommend "Standard Specifications for Riveted Steel Elevated Tanks and Standpipes," published by the American Water Works Association, as a base for more detailed specifications.

GOLDEN-ANDERSON VALVE SPECIALTY CO.

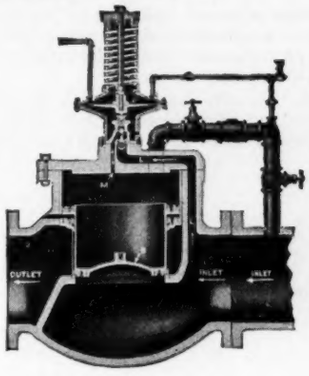
1350 Fulton Bldg.

PITTSBURGH, PENNA.



THRU-FLOW CONE VALVE

Afford full pipe line flow without friction loss. Always oil lubricated. Axially unseats before it rotates without friction, rub or wear. Especially desirable for sewage disposal service.



ALTITUDE CONTROL VALVE

Assures uniform water level in tanks, standpipes and reservoirs. Suitable for use in single or two-way line service. Heavy internal bronze mounting and air and water cushioning makes valve indestructible. Sizes to 24″.

CUSHIONED FLOAT VALVE

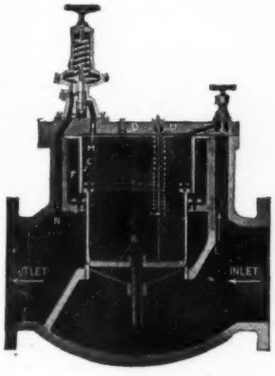
Automatically maintain uniform water levels in tanks, standpipes, etc.

Instantly adjusted to operate quickly or slowly.

Cushioned by water and air, sizes ½ to 24″.

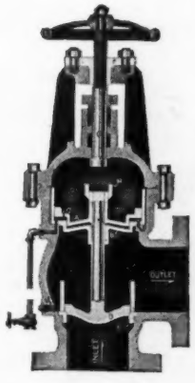
CONTROLLING FLOAT VALVE

Ideal for heaters, vats, tanks, etc. Valve entirely self-contained and operates without water spill. Sensitive in operation and indestructible due to air and water cushioning and heavy bronze mountings. Sizes to 24″.



WATER REDUCING VALVE

Assures positive control of low pressure. Air and water cushioning prevents shock or hammer. Supplied with single or dual pilot controls for any service. Sizes to 24″.

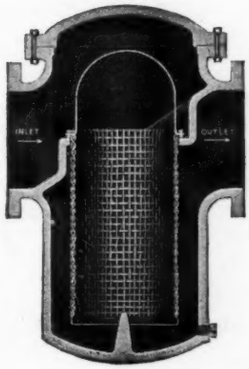


NON-RETURN VALVE

Protect life and property against boiler tube ruptures; also, furnished in Triple Acting style to protect against steam line breaks. Supplied for low and high pressure steam service. Sizes to 12″ in angle, globe or elbow patterns.

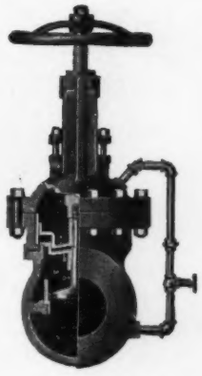
WATER STRAINER

Large capacity with minimum friction loss. Strainer basket quickly accessible and easily cleaned. Basket mesh furnished to suit any service conditions. Sizes to 24″.



ENGINE STOP VALVE

The most efficient and dependable automatic stop valve to prevent overspeeding of turbines, engines, etc. Automatically tripped by mechanical or electrical control. Furnished angle or globe patterns to 12″ sizes.



WATER HAMMER CORRECTIVES

By RICHARD BENNETT, Hydraulic Engineer
City Engineer's Office, Phoenix, Arizona

PIPE LINES subjected to sudden shock or recurring vibration due to water hammer, become weakened and operate inefficiently. This destructive nuisance may also pull pipe hangers loose or create damaging leaks.

Destructive water hammer may actually be present in water lines even where its presence is not indicated by violent hammering and noisy vibration. For the most part this fact is not generally realized or recognized.

Cause of Water Hammer

If flow in a pipe is suddenly stopped, the energy built up by the flowing water produces a high pressure which may result in a terrific impact. This is caused by the non-compressible liquid (water) rebounding in the supply lines. This rebound impact is due to the sudden stopping of water flow every time a faucet or valve is closed. Power for operating hydraulic rams, which force water many times higher than the static head on the power water supply line, is thus generated by intermittent quick closures of valves attached to the ram.

In order to have conception of this force in small pipe, when water hammer occurs the pressure is increased by about 60 pounds per square inch above the flow pressure for each foot per second of sudden decrease of velocity of flow. This means that if a flow velocity of 10 feet per second is stopped instantly, a maximum water hammer pressure rise of (10x60) 600 lbs. per square inch may occur. This pressure is added to the normal static pressure at the point of impact.

Destructive water hammer must be eliminated to avoid the nerve-racking noise from which the term is derived; to reduce stress in the pipes; to safeguard plumbing fixtures; to avoid costly leaks and repairs; and to prevent operating delays.

Correctives

Relief from destructive water hammer may be accomplished by relief valves, but these can be used only in special cases. Relief can be obtained by air chambers, but the difficulty of keeping air in the chamber makes this method impractical under many conditions of operation. In many instances positive and permanent relief can be obtained by the installation of surge suppressors. These are sometimes given trade names such as shock absorber, water hammer arresters, etc. Just as the automobile shock absorber absorbs the bumps of the highway, so does a good surge suppressor cushion the terrific impact of water rebounding in the piping system.

Unless a surge suppressor is installed, the water backs up with terrific force and continues to bound and rebound in the pipe lines every time the flow of water is suddenly checked. With a good surge suppressor this pounding and hammering is overcome by absorbing and dispelling the shocks, and strain in the pipe is relieved.

In selecting a surge suppressor it is desirable that it afford protection from water hammer under all conditions of service; that it be easy to install; require no periodic adjustments; require little or no maintenance; that it operate in any position; that it be unaffected by hot water; and that it be reasonably priced.

Under some conditions it is possible to determine in advance the behavior of the surge suppressor, and a method for calculating the degree of relief from water hammer pressure for a given piping layout is obtained by the relation between useful volume of air in the surge suppressor for the various rates of discharge through the pipe line.

Theoretical considerations are generally to assume the discharge suddenly stopped by valve closure. This seldom occurs in actual practice. The size of the surge suppressor to be selected for each installation should be adequate to reduce the maximum water hammer pressure that can be caused by quick closure of any one valve or faucet.

In Fig. 1 is illustrated the action of water hammer as recorded on a time-pressure diagram showing the incessant impact shocks and pressure fluctuations. The system is free of this shock effect (even though hammering may not be heard) only during those hours when no water is being drawn.

When an efficient surge suppressor is installed the time-pressure chart recording should look something like the chart shown in Fig. 2. A proper suppressor will quiet the water hammer by dissipating impact shocks and overcoming the pressure fluctuations

Surge Suppression Devices

Perhaps you have come to the conclusion of "Why not eliminate the source of the water hammer?" Quick closing valves are the cause of most of this trouble, but modern equipment of the present

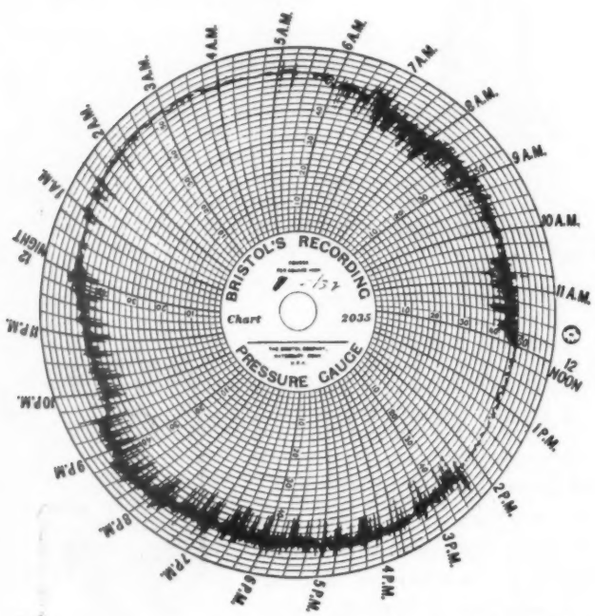
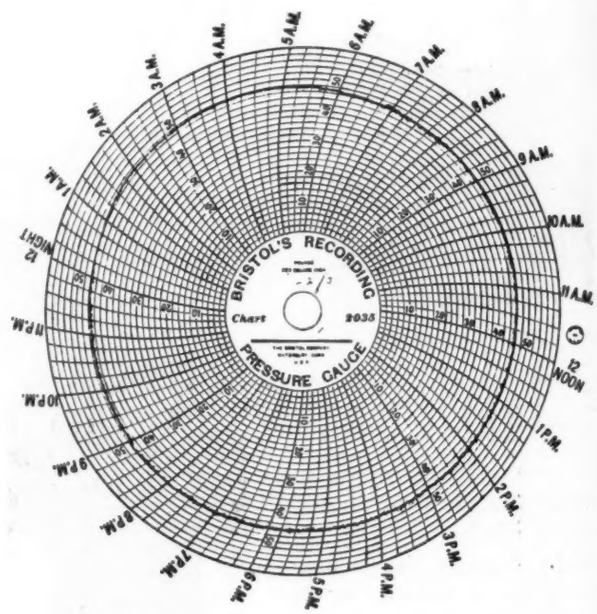


Fig. 1—Reveals the incessant impact shocks and fluctuating pressures when water hammer is present.



A Story Told by Two Record Charts

Fig. 2—After the installation of a good surge suppressor the record chart should look something like this.

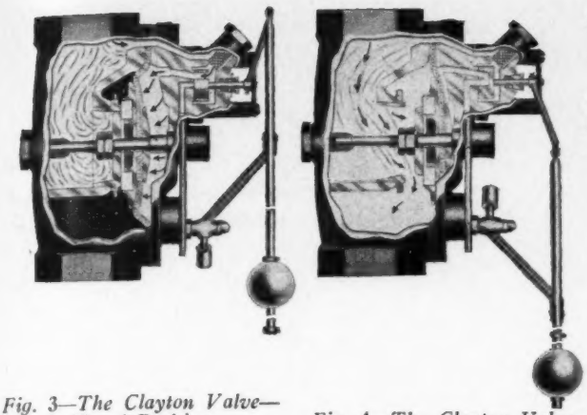


Fig. 3—The Clayton Valve—Closed Position
Is a quick closing valve designed to preclude hammer by uniform and governed rate of closure.

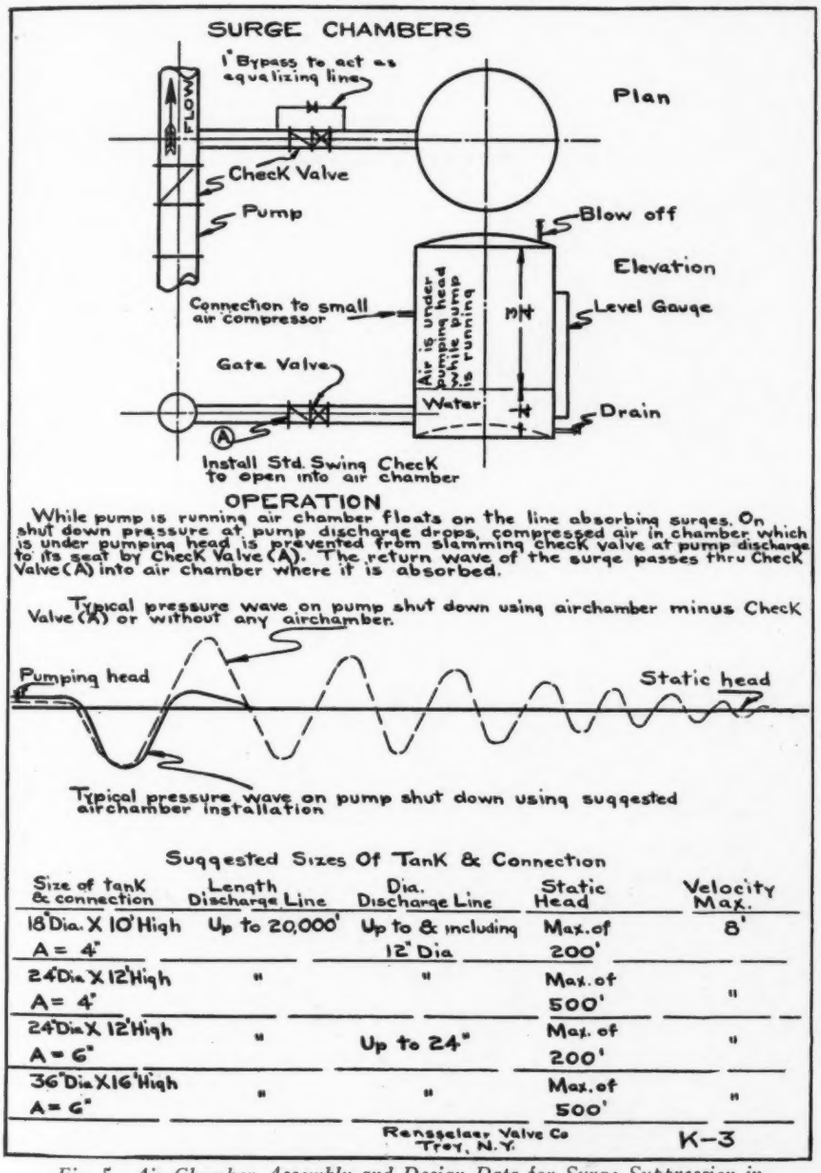
Fig. 4—The Clayton Valve—Open Position.
Always wide open or fully closed, functions well in rapid fillings of vats, tanks, etc.

day increasingly requires quick closing valves and water customers insist on quick closing faucets and fixtures, therefore water hammer troubles may be expected to increase, rather than decrease, in the future in most water works.

Valve manufacturers, as a group, have done very little to produce equipment to meet this situation, however, the Clayton valve has been designed for this purpose. It can be adapted to almost any type of flow control problem. Figs. 3 and 4 show this valve in the closed and open position. The arrows show that the valve is kept closed by water pressure on the back of the diaphragm. This valve can be furnished with an adjustable needle control for regulating the closing speed to meet any given condition. The illustrations show float control for rapid tank filling and smart shut off, but the manufacturer states that it can be adapted to remote, automatic, manual, elecric, or any type of control desired. Fig. 4 shows that when pressure behind the disc is removed the line pressure forces the diaphragm assembly away from the seat. This valve is always wide open or fully closed, and closes at a governed uniform rate to eliminate line shock when the shut-off occurs.

Relief Valves

Relief valves are sometimes used to eliminate water hammer but they can be used only in special cases, due largely to the spill of water which must be cared for, and do not operate except under


SURGE CHAMBERS
1" Bypass to act as equalizing line
FLOW
Check Valve
Pump
Plan
Blow off
Elevation
Connection to small air compressor
Air is under pumping head while pump is running
Level Gauge
Gate Valve
Water
Drain
A
Install Std. Swing Check to open into air chamber
OPERATION
While pump is running air chamber floats on the line absorbing surges. On shut down pressure at pump discharge drops, compressed air in chamber which is under pumping head is prevented from slamming check valve at pump discharge to its seat by Check Valve (A). The return wave of the surge passes thru Check Valve (A) into air chamber where it is absorbed.
Typical pressure wave on pump shut down using airchamber minus Check Valve (A) or without any airchamber.
Pumping head
Static head
Typical pressure wave on pump shut down using suggested airchamber installation
Suggested Sizes Of Tank & Connection

Size of tank & connection	Length Discharge Line	Dia. Discharge Line	Static Head	Velocity Max.
18" Dia. X 10' High A = 4"	Up to 20,000'	Up to & including 12" Dia	Max. of 200'	8'
24" Dia X 12' High A = 4"	"	"	Max. of 500'	"
24" Dia X 12' High A = 6"	"	Up to 24"	Max. of 200'	"
36" Dia X 16' High A = 6"	"	"	Max. of 500'	"

Rensselaer Valve Co Troy, N.Y. K-3

Fig. 5—Air Chamber Assembly and Design Data for Surge Suppression in Centrifugal Pump Operation.
Courtesy Rensselaer Valve Co.

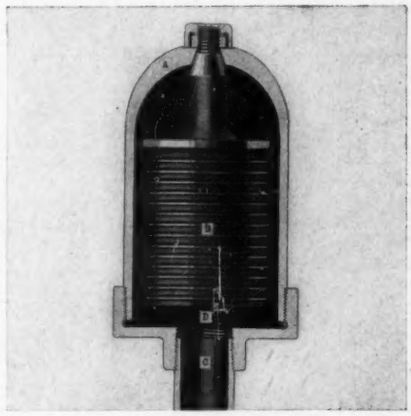


Fig. 6—"Wacor" Water Hammer Arrester
Position of bellows compression unit at time of normal pressure.

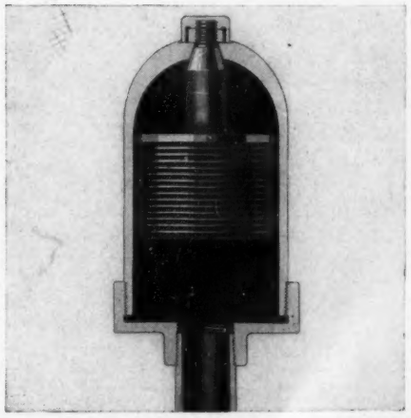


Fig. 7—"Wacor" Water Hammer Arrester
Position of bellows compression unit when absorbing hammer shock.

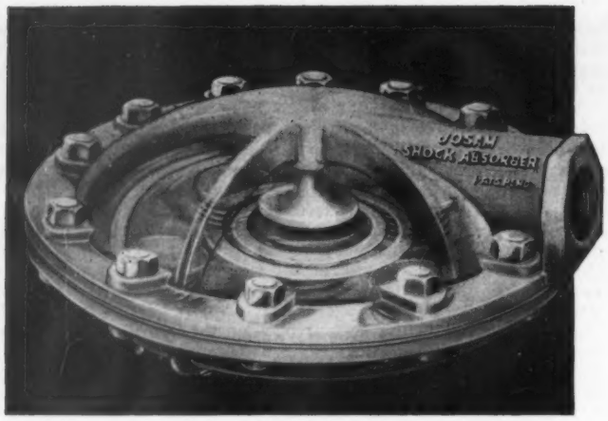


Fig. 8—The Josam Shock Absorber
Phantom view showing four coil springs in dry side of diaphragm chamber, which absorbs and dissipates the shock.

high surge pressure. However, many have secured satisfactory results from these devices at pumping stations and hydro-electric plants where water spill is not a problem.

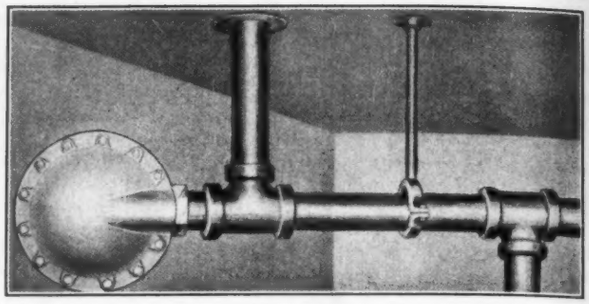


Fig. 9—A Josam Shock Absorber
(Installed at typical location point on the end of a long straight run of pipe.)

Air Chambers

Relief from destructive water hammer may be accomplished by air chambers, but the difficulty of keeping air in the chamber makes the air chamber impractical, unless given close attention, or air recharging can be automatically done with compressors.

Fig. 5 illustrates an air chamber assembly. When the pump is running the chamber of compressible air floats on the line absorbing or cushioning surges. When a pump shuts down pressure at the discharge drops instantaneously and then the back surge follows. Compressed air in the tank, which is under pumping

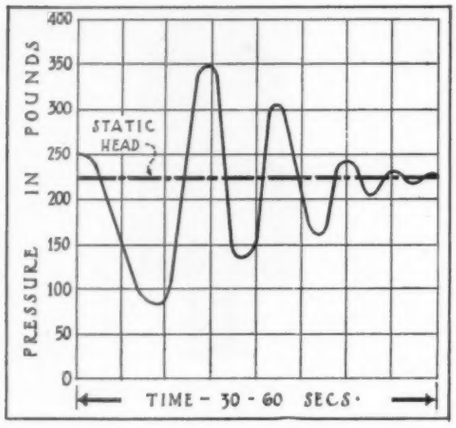


Fig. 11—The Effects of a Slow Closing Check
The lag in closing is responsible for the marked surge and hammer pressure.

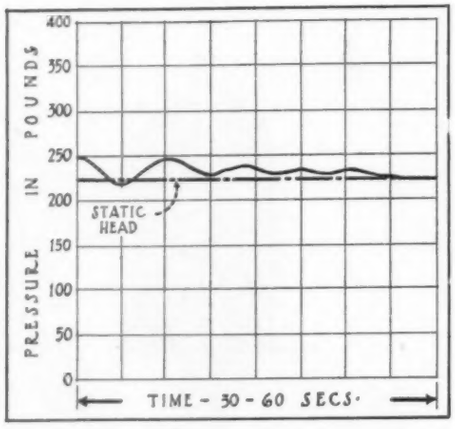


Fig. 12—The Effects of a Quick Closing Check
Showing the results of rapid closure when effectively timed ahead of the first rebound of the water column.

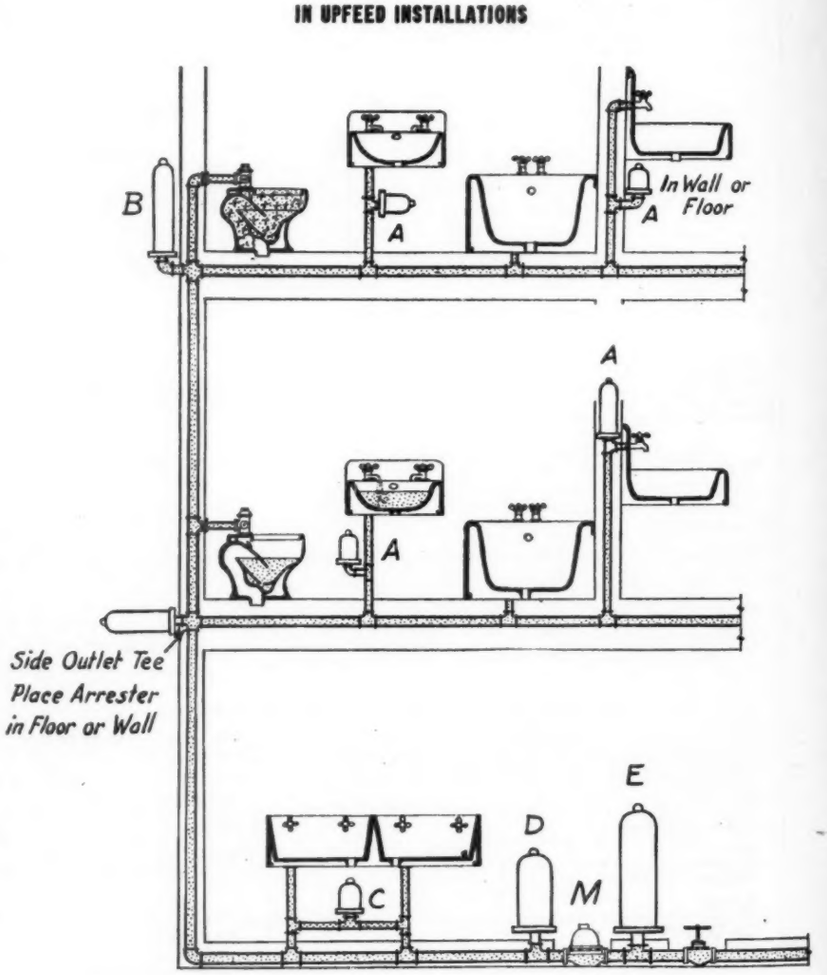


Fig. 10—Illustrating Other Typical Location Points for Shock Absorbers and Hammer Arresters

Fig. 13—The Smolensky Check
A wholly mechanical valve

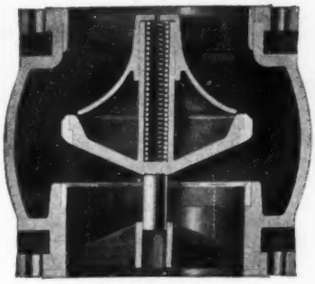
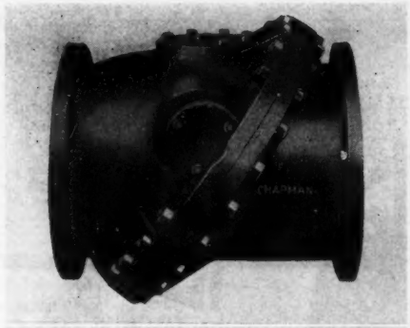


Fig. 14—Interior of the Smolensky Check
Spring force enables this valve to close slightly in advance of cessation of flow away from the stopped pump.



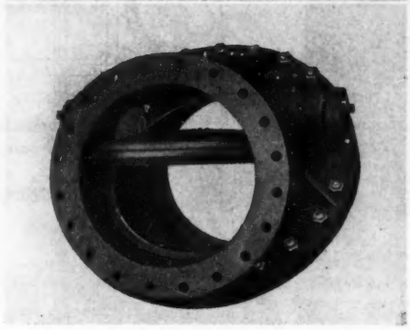


Fig. 16—Chapman's "Non-Slam" Check
Features the streamlined tilting disc, closing gradually to completion at instant of flow cessation away from pump.

originates in the municipal distribution system and affects the consumers' service line or plumbing installation.

Another surge suppressor for small piping systems is the Josam Shock Absorber, which is shown in Fig. 8. It operates on the diaphragm principle and is very efficient when properly sized to the individual problem. This suppressor absorbs shock by compression of four coal springs very much after the manner of the coil springs known as Knees in modern automobiles. The diaphragm moves out against these springs located on the dry side of the unit.

Location of Suppressors

Practice varies widely as to the proper installation point for surge suppressors; some will place a suppressor at the end of all long runs of pipe; others install at the end of a battery of fixtures, but it seems agreed that it should be placed *as near to the valve causing the water hammer as is permissible.*

It is desirable to place the suppressor so that the opening is at the bottom if possible. This will avoid hazards from sediment being washed into the casing. Wherever a greater capacity is required to reduce water hammer pressure than can be furnished by a single suppressor, any number can be placed in the pipe line, either in scattered positions or together at one fitting.

Figs. 9 and 10 show typical installation points for suppressors of this general type.

head, is prevented from slamming the check valve on the pump discharge line to its seat by the functioning of check valve (A). The return wave of the surge, however, can pass through the check valve (A) into the air chambers where it is markedly cushioned and gradually absorbed during gradually diminishing surges.

For most all cases of water hammer, of the type caused by quick closing valves on all but the largest lines, a surge suppressor which may be attached to the pipes and operate automatically without maintenance is to be preferred. Of this type the "Wacor," shown in Figs. 6 and 7 is very reliable. This suppressor has been thoroughly engineered for small piping systems, the manufacturer having financed an extended research program in the hydraulic laboratories of the University of Wisconsin, where all possibilities of this equipment were rather thoroughly explored.

"Wacor" Water Hammer Arrester is manufactured in a number of sizes for pipe lines up to 10-inch in diameter. It is a combination mechanical-pneumatic type of absorber constructed with a closed metal bellows or compression compartment. The latter is filled with a special compressible emulsion so that air can neither escape nor be absorbed by the water. It is particularly adapted to all ordinary house services where water hammer exists or where high pressures engendered by rapid valve closure are damaging piping and fixtues.

When this suppressor is put on the line the sealed (compression chamber or bellows (containing the emulsion) is slightly compressed as the water pressure is turned on the system. This is shown in Fig. 6, with the bellows at resting position. If now a valve or faucet is opened and water flows through the pipe, the bellows expands somewhat due to the reduction of the pressure at its base. As the valve or faucet is closed the velocity of the water in the pipe line is reduced, resulting in an increase of pressure. This compresses the bellows, resulting in an increase of pressure on the emulsion sealed within the bellows. The pressure inside and outside of the bellows thus becomes equalized. Work done in compressing the fluid emulsion within the bellows is responsible for the absorption or damping of the hammer pressure in the pipe line to which the arrester is connected. This is shown in Fig. 7, and illustrates the position of the bellows, when absorbing the hammer shock.

This type obviates the need for the attention which air chambers require. They are used with quick action valves and high velocities of flow, and can be used where water hammer pressure

Water Hammer with Centrifugal Pumps

The use of centrifugal pumps presents a major problem in the control of surge water and minimizing of water hammer. When the power is shut off the water in the discharge line reverses its direction of flow and if not controlled will cause reversal of pump and motor.

The installation of the flap type check valve with centrifugal pumps increases the effect of surge waves and water hammer, if not actually being responsible for such. Ordinary check swing valves, due to slamming, cause abnormal disturbances in the pipe lines. Slam leads to serious trouble because of the resulting vibration of pipe lines and adjacent structures, opening up the pipe

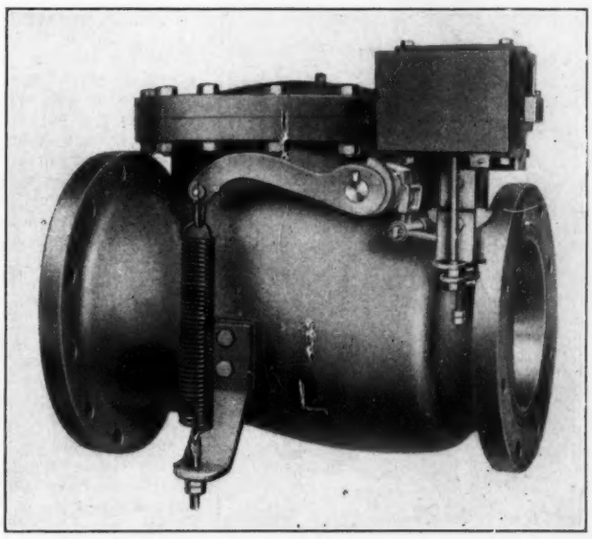


Fig. 15—The Rensselaer Automatic Power Check
Features low-friction clear-way and quiet spring loaded closing of the flap ahead of cessation of flow away from the stopped pump.

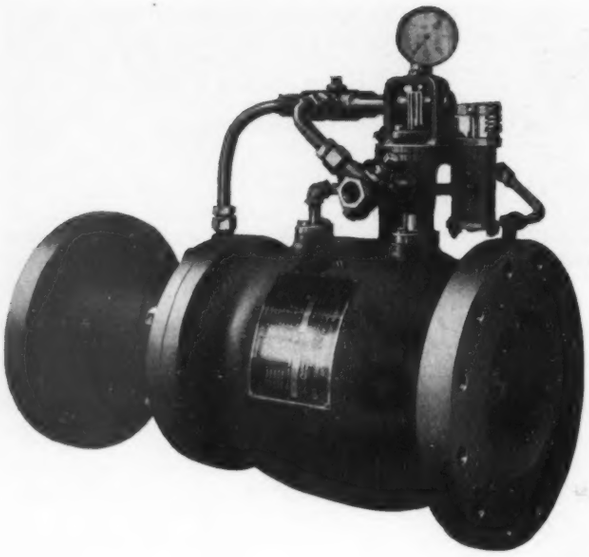


Fig. 17—Exterior of this automatic needle-type check.

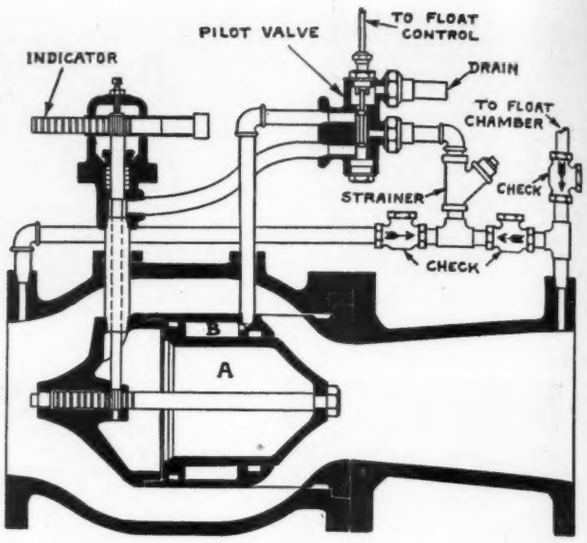


Fig. 18—Sketch revealing design and functioning of the valve.

Pelton's Larner-Johnson Check Valve

Fig. 19—The Pelton Surge Suppressor
A high grade relief valve for use in conjunction with automatic check valves.

joints. The resultant water hammer frequently ruptures the pipe line. The common swing check valve is fundamentally wrong in its design to be of use for such service.

Check valves may be grouped into two general classes: (a) slow closing and (b) quick closing.

Most slow closing valves are, however, impractical, even though theoretically correct. The action of this type of valve with respect to water hammer may be shown by the illustration in Fig. 11. In practice there may be little or no audible water hammer with this type, but as indicated, there is a serious pressure rise due to the surge which may be disastrous to the pipe lines and fittings.

A check valve should generally be of a type that closes *before* the pressure reverses from the immediate low to the quickly ensuing high. Many have found that this is the only type that will give proper service. The quick closing check valve provides for eliminating surge shock at the valve seat, and quickly returns the surge wave to static pressure before any appreciable surge oscillation can be set up in the discharge line. All discharge lines, especially of the larger diameters, are at least to some degree elastic and will permit so-called harmonic surges to develop. When the discharge column of water is halted before a reversal of flow takes place, these surges will not cause a dangerous pressure rise. The action of the rapidly closing type of check valve, with respect to ensuing water hammer, may be illustrated as shown in Fig. 12. These two pressure recordings (Figs. 11 and 12) show that the pressure rise has been reduced from about 50 per cent excess head to about 10 per cent over the static pressure through the effective timing of closure of the automatic check.

The Smolensky Check

One type of check valve used for this purpose is the Smolensky check valve, which is illustrated in Figs. 13 and 14.

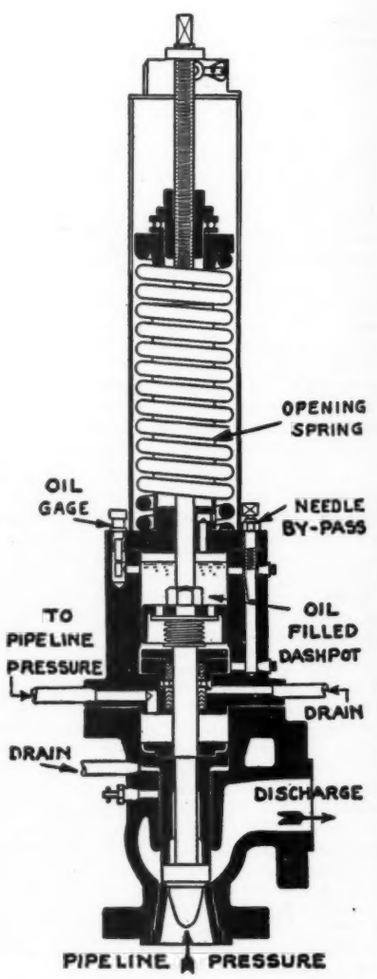


Fig. 20—The Pelton Surge Suppressor
Sketch revealing working parts and functioning of this surge dissipating unit.

This valve is designed to close just a little in advance of minimum pressure at the pump, so as to insure absolute freedom of danger of reversal of pump and motor. It also prevents mechanical shock at the check valve for the spring action is counterbalanced by the back pressure against the diminishing pump discharge. The mechanism of this valve is shown in Fig. 14.

The seat position of the Smolensky valve is dependent entirely upon the velocity of the flow and the action may be understood by reference to the homely analogy of a laborer following a loaded truck up a steep incline. By chocking the wheels at the slightest tendency to stop, a small stone is sufficient to hold the load from reversing. Allow the truck to fall back a few feet and the truck load will be in danger, since its stopping is much the more difficult.

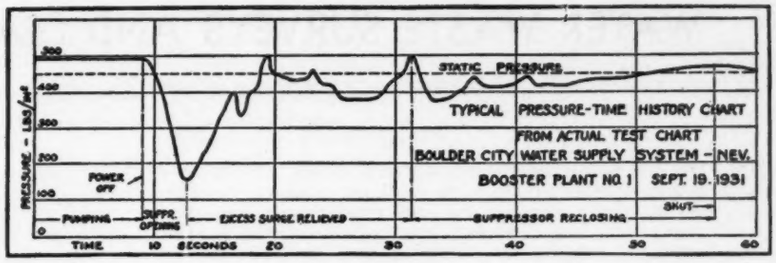


Fig. 21—A Real Performance Record
Showing the result of combination of automatic check and Pelton Surge Suppressor on a heavy duty job under 490 lbs. static head. This race was won in approximately 50 seconds flat.

Rensselaer's Power Check

Fig. 15 shows the Rensselaer quiet-closing power check valve. This check operates with an electric solenoid. When the pump is started the swing check is opened and held out of the flow in a locked position. Instantly that the power is released the solenoid automatically releases the swing check and the power of the spring instantly closes the check ahead of the reversal in direction of flow.

Chapman's Tilting Disc

Fig. 16 illustrates the exterior and interior of the Chapman non-slam tilting-disc check valve. This type of check closes with a minimum of slam. Friction losses are also very substantially reduced in the design. The disc is pivoted just above its center, which results in a cushioning effect resulting while closing. This is due to the fact that the portion of the disc above the pivot partially balances the portion below. The seat and disc rings are beveled and the disc drops into the seat in the body with a closing action which gives a further cushioning effect. This valve in closing reaches its seat at exactly zero velocity in the line. The angle of the seat is so incline that the distance the disc must travel from its wide open position to its seat is reduced to the minimum consistent with good design.

Larner-Johnson Check

Fig. 17 shows the exterior of the Pelton-Larner-Johnson check valve, and Fig. 18 shows how it functions.

This check is normally automatic in operation but may be arranged for manual control. With the control equipment which is built into this type of check valve the time of closing may be regulated to best suit local conditions. It is designed for installation on the discharge side of a centrifugal pump, its best function being to close at the instant of power failure and to prevent both reversal of the pump and motor and wastage of pumped water.

Pelton Surge Relief Valve

In many cases of operating centrifugal pumps, surge and water hammer cannot be eliminated by the mere installation of a check valve alone regardless of type. In such cases it is also necessary to install additional equipment such as an air tank, relief valve or such. For difficult situations one of the best known pieces of equipment for this purpose is the Pelton Surge Suppressor, shown in Figs. 19 and 20. This surge suppressor is essentially a high grade relief valve, designed for use with a check to relieve surge pressure in a pump discharge line incident to pump shutdown. It may be operated either by water pressure, solenoid or mechanical interconnection with the check valve. To permit a sufficiently rapid closure of the check and thereby prevent dangerous reversal of the pump after the power shut-off, the surge suppressor is essential to relieve the resulting pressure surges. The surge suppressor *opens with the drop in pressure* following shutdowns, remaining open to relieve the surge which follows. It then automatically closes at an adjustable rate.

The action of the Larner-Johnson Check Valve and the Pelton Surge Suppressor in combination are shown in the results obtained on the accompanying time-pressure diagram (Fig. 21) of the Boulder Dam water supply to Boulder City. Operating under a static pressure of about 490 pounds, the time-pressure diagram (Fig. 21) shows that it took about 50 seconds only for the pressure head to become normal static head after pump shutdown, during which interval the rise in pressure was not more than 10 pounds above static.

Studying and Recording Surge Conditions

In actual operating practice it is seldom that any two cases of surge or water hammer are identically alike. The simpler cases of surge in building pipe systems may usually be overcome with the low cost type of surge suppressors previously shown. With the more complicated cases, especially those affecting water distribution systems, the conditions become very involved and it is usually necessary to make a complete survey of the actual facts pertaining to each individual case before it can be properly handled. It is necessary to determine the amount and intensity of water hammer and thereafter take new records in order to determine the results obtained from equipment installed, or other corrective measures applied.

For this purpose it is essential to employ equipment for recording pressure-time diagrams of the disturbance. Fig. 22 shows Bachrach's Chronomatic Drum, which gives a pressure-time diagram, revealing clearly the pressure pulsations in the pipe line during a certain time interval. Fig. 23 shows this equipment in carrying case for ready portability. This is a time-pressure indicator originally designed for testing high-speed diesel engines. It has unrestricted speed selectivity and instantaneous speed indication. The operation is simple and requires no skill or special training. The time-pressure diagram for the Boulder City line was taken with this equipment.

Few engineers have had wide contact with problems calling for relief from water hammer in pipe lines or piping systems. The present literature on the subject is neither broad nor inclusive, being largely devoted to the extreme technical and theoretical phases of the subject. On this account it has been my purpose to confine this discussion to a few practical considerations.

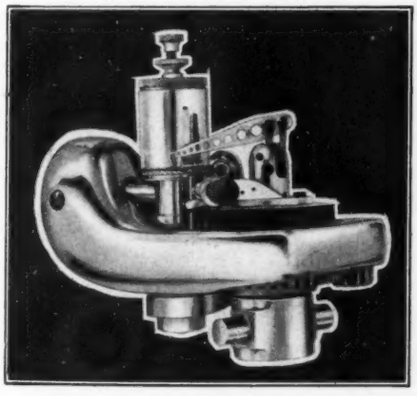


Fig. 22—Bachrach's Chronomatic Drum
Its use provides the all important time-pressure chart in studying water hammer and attainments resulting from corrective measures and functioning of equipment.

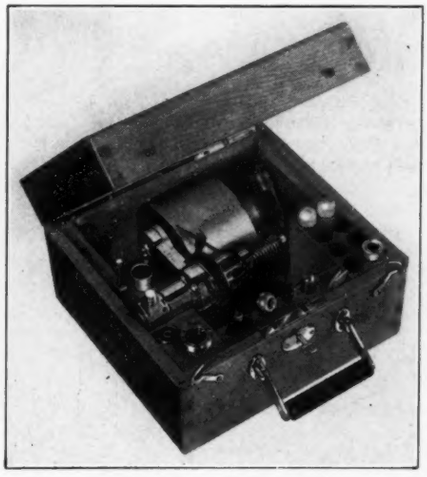


Fig. 23—Bachrach's Portable Recorder
Is compact and useful in surge study on pipe lines and distribution systems.

WATER WASTE SURVEYS AND LEAKAGE CORRECTION

By EDGAR K. WILSON, Chief Engineer
The Pitometer Co., Inc., New York, N. Y.

IN THE old days when water was "free" except for the labor of lugging the buckets from the well, no check on its waste was used nor was one necessary, since that labor in itself was a sufficient check; and if an individual were so ambitious as to carry unlimited supplies of water, the thriftiness of the wife would soon curb his energy when the requirements were reached for immediate uses or the available vessels were filled.

With the introduction of pumped water, however, this guard against waste in the houses was to a considerable extent relaxed, and with the installation of more modern plumbing, not only the use of water increased, but also the waste; so the water meter was devised, and the meter, where proper maintenance has been provided, has ever since been the most efficient watchdog against a careless or wilful water waste.

Again reverting to the early days, not much thought was given to the leakage from the mains, unless it came to the surface. Since many communities had no sewerage systems, the chances for the water to get away underground were far less than at present where sewer trenches and other sub-surface structures, in addition to the water trench, make easy paths for escape without showing any signs at the surface. Such leaks may and often do continue for years without discovery. Leaks do not tend to close up as time goes on—on the contrary they may become large enough to cause a serious drain on the system.

Where there is a station meter which records the continuous flow of water, a large break will be automatically recorded and means may be taken at once to discover and remedy the trouble. Smaller leaks are likely to be hidden in the daily consumption, and as they grow in size and their number is increased, the total consumption of the system gradually creeps up and up until pumping capacities are found approaching their limit and pressures under heavy draft cannot be maintained.

Benefits to Be Derived from Leak Location Work

The location and repair of leaks, therefore, benefits a water works system in several ways:

1. By conservation of the primary supply.
2. By saving treatment and pumping costs.
3. By postponing the installation of additional pumping equipment.
4. By eliminating or postponing the need for additional supply mains.
5. By eliminating the loss of head due to unnecessarily high velocities.
6. By elimination of possibilities of accidents due to undermining streets or buildings.
7. By increase of water and pressure available for fire fighting uses; also better residential pressures.
8. By decrease in the amount of water flowing into the sanitary and storm sewers.
9. By decrease in cost of handling an unnecessary amount of water in sewage treatment plants.

Other benefits may be observed in individual instances, but the above are sufficient to indicate that underground leakage is a matter of consequence, and one which should receive the attention deserved in the operation of every water works plant.

Methods of Detection and Elimination

The elimination of underground waste can be accomplished only by a thorough and painstaking survey of the entire system, *block by block*. Unless the water actually entering each block through the night hours of minimum consumption is measured, it is not possible to know certainly whether leakage exists. Such a measurement also eliminates the necessity of looking for leaks in blocks when it is shown that no flow exists which can not be accounted for as the reasonable consumption of such blocks.

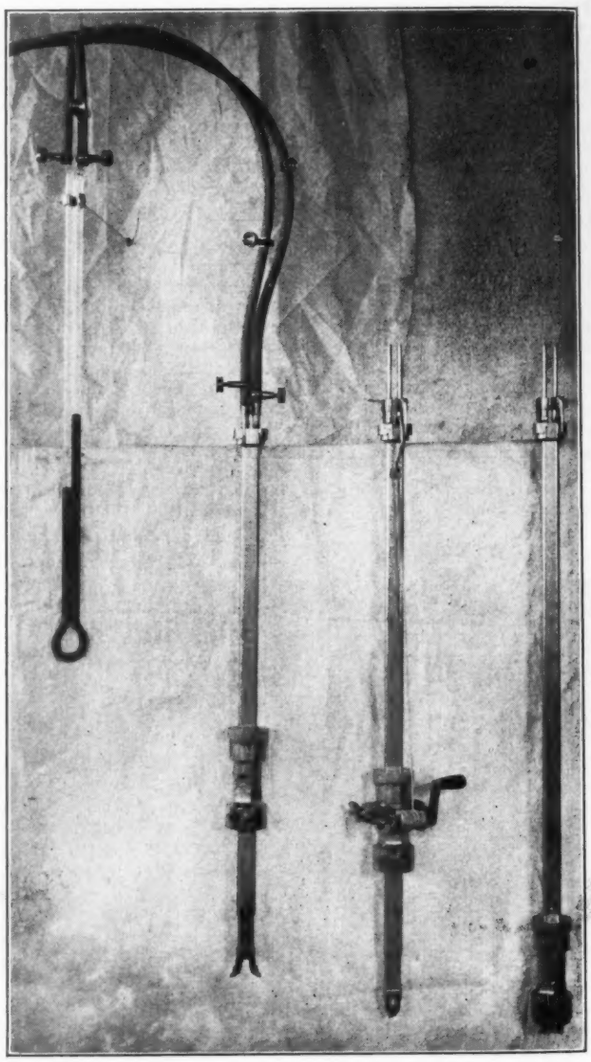
The Pitometer Survey

The best way of making these investigations is by a Pitometer water waste survey. Starting with the sources of supply or the pumping stations the survey tests the gravity supply lines for leakage, the pumps for slippage and efficiency, and the station meters for accuracy; and from that point conducts an audit of the water throughout the entire underground system.

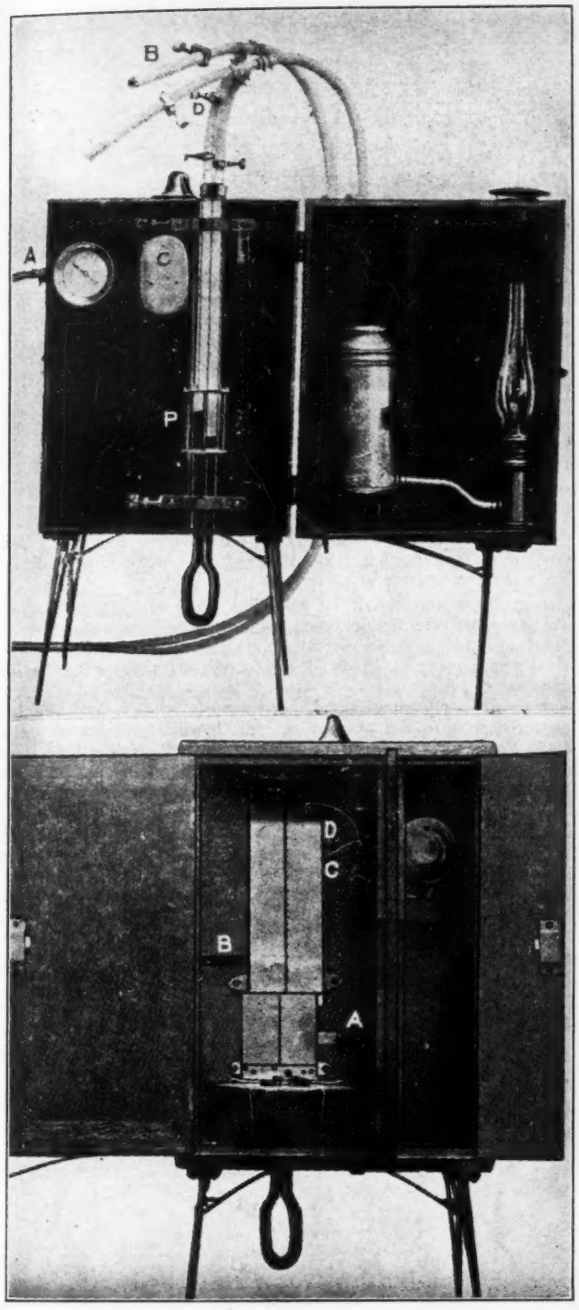
The survey is carried on by measurements at gauging points which are installed throughout the system by inserting 1 inch corporation cocks at selected points in the mains, through which a Pitometer rod meter is introduced.

The Pitometer and Recorder

The Pitometer is an instrument based on the well known Pitot tube, adapted for the measurement of water in pipes under pressure. However, instead of having an upstream orifice facing the stream and a static orifice at right angles to the flow, the Pitometer has two identical orifices, one of which faces upstream and the other *downstream*. These orifices are connected to a glass manometer partly filled with a liquid of specific gravity higher than that of water, colored for easy observation of deflection, and also for the more effective photographing of flow records in the recorder, the description of which follows. With the apparatus entirely cleared of air, and the orifices set at the center of the pipe and aligned with the stream, a differential velocity is obtained which gives a deflection in the manometer. With the specific gravity of the indicating liquid known, the velocity and the rate of flow at the orifices can be readily determined for any given deflection observed or recorded.



Pitometer Rods and Manometer



The Photo-Recorder

The oil light makes a photographic picture of the differential levels in a manometer tube. The lower view is the recorder from the rear. The revolving drum carrying photographic paper has been removed from the left compartment to show the prism attachment.

The "Pipe Factor"

To arrive at the quantity flow accurately a "pipe factor" is required. This factor is established by what is known as "traversing" the pipe. This is accomplished by taking readings on the manometer with the orifices set at various selected points across the pipe, fairly close together near the walls, and further apart as the center is approached. These points are plotted on cross section paper and a smooth curve drawn through them. Rings of equal area, representing the complete cross section of the pipe (usually five in number), are laid down on this curve. The manometer deflection recorded at the center of each ring is taken from the curve. The sum of the square roots of these deflections divided by the square root of the deflection at the center gives the essential "Pipe Factor." This factor is nothing more than the ratio of the mean cross sectional velocity of the water flowing through a particular main to the center velocity. Then, this factor is applied to the velocity of flow obtained with the Pitometer when the orifices are at the center of the pipe.

Determining Exact Flow

The actual diameter of the pipe is measured by use of a special caliper. With the area of the pipe thus determined and the average velocity across the pipe, determined as above, the quantity of water flowing is computed.

To record the deflections of the manometer liquid over a period of time, as, for instance, twenty-four hours, the photo-recorder is used. The manometer is clamped to this instrument and by means of a lamp a record is made of the varying deflections on a sheet of photographic paper. The sheet of recording paper is carried on a clock driven drum, the speed of which is controlled by different gears, so that one revolution of the drum may take place in 12, 24, or 48 hours as desired. After the record is developed, the flow at any time during the period of the run can be determined as well as the time at which it occurred. It is evident that several of these recorders can be set up at various points to attain simultaneous flow records, without the need for having observers on the job. Furthermore, the photographic records are the most dependable sort of records.

Making the Survey

As previously stated, a Pitometer survey should start at the pumping station or source of supply, after which district measurements are made for a period of twenty-four hours throughout the entire distribution system. The districts consist of areas, selected with due consideration of pressure and flow conditions. These areas must be subject to isolation by closing all mains leading into them except one, on which the Pitometer apparatus is installed. It is not usually the case that the main feeders from the station or throughout the system can be included in any district, since the closure of such mains will almost always so affect the pressures and supply that conditions would not be normal. These feeders are therefore tested by themselves without shutting down, or possibly with shut-off of short duration only. Such shut-offs may be made during hours where no inconvenience of importance will result.

An inspection of the photographic record of the district measurement shows the relation of the total daily consumption and the important tell-tale minimum night rate of the district, which is a definite indication of the existence of waste. Since all important meters in the area under test are read during the time of flow measurement and checked for the time of minimum consumption, a correction of these amounts applied to the totals leaves the amount which must be charged to legitimate use, leakage—and, as in some cases, illicit use through unmetered connections.

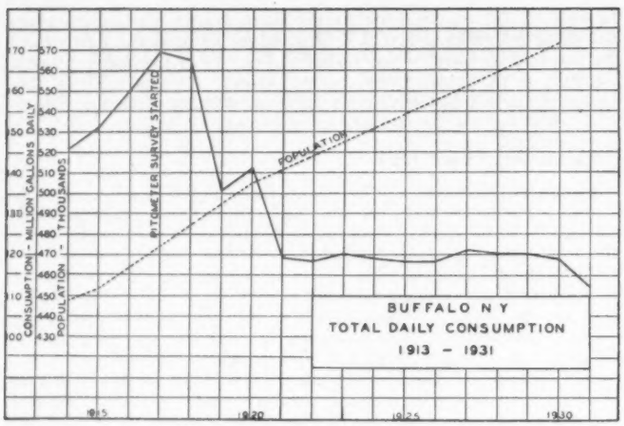
With this as a basis, the district is then subdivided during the night by closing off each block in turn. Any flow which was present in the block before it was shut off will be indicated by a drop in the deflection as recorded on the photographic chart. While making shut-offs each block is tested for tightness to be sure that all valves are holding, and that there is no unrecorded connection feeding into the block. During the subdivision the time of closing each valve is recorded.

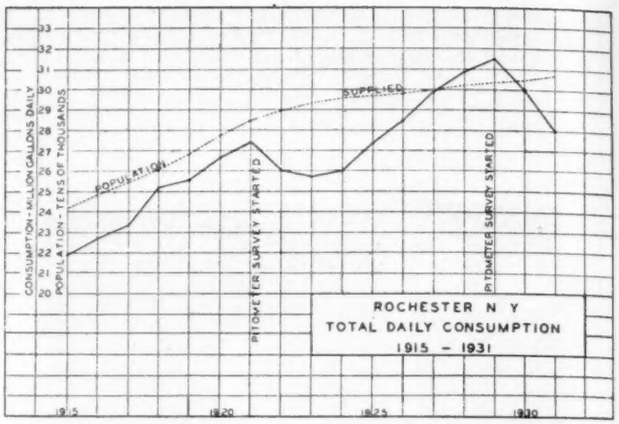
With the subdivision chart completed, the times are plotted and the result of the shutting down of each block is observed, the deflection being measured from the photographic record as on the plain manometer.

Leak Location and Meter Checking Next

The results of the subdivision are carefully studied with reference to the amount of water which may be considered to be legitimate consumption. Night rates on large meters are taken into account and investigations are made in all blocks which still appear to have an abnormal consumption. These investigations are made with various listening devices placed on service stop cocks, hydrants, on water pipes inside of houses, or on the street surface; and leaks are located so closely that it is only very rarely that more than one hole must be opened for repairs.

During the course of the survey large industrial meters are tested in place without disturbance, so that their actual condition previous to the test is determined. This allows the test to be carried on under the actual working conditions of the meter which is not possible if the meter is removed to the shop for testing.





Two Rather Typical Records of Reductions in Water Pumped Following Water Waste Surveys
In the case of Rochester it is observed that following each survey the results of leakage correction and waste reduction are very evident.

Detecting Illicit Water Takings

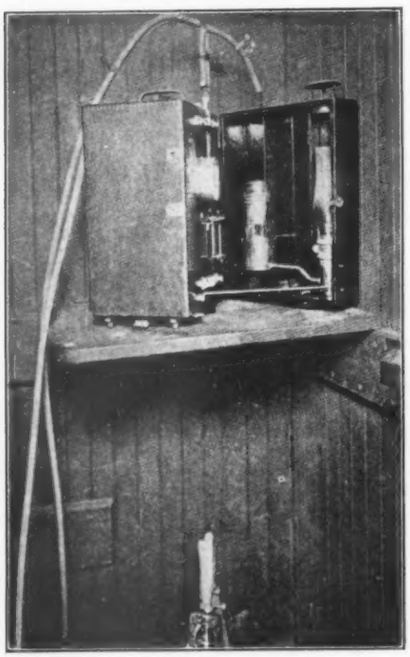
Fire lines without meters are sometimes used for other purposes than fire extinguishing inside of manufacturing plants. While such uses, if only occasional, cannot always be detected except by long continued measurements, or by good fortune in happening to make the measurement at just the right time, if the practice is carried on at frequent intervals, the survey will furnish evidence so that back bills may be rendered for the unpaid-for water.

At the close of the survey a report is rendered which gives all details of the survey. A list of defective valves is furnished, which is of especial value, since ordinarily about ninety per cent of the valves in the system are operated during a Pitometer survey. Suggestions are also offered in regard to locations of new valves, and other matters which make for the more efficient operation of a water works plant. One highly important consideration is that pumping efficiencies are revealed, and design deficiencies are uncovered.

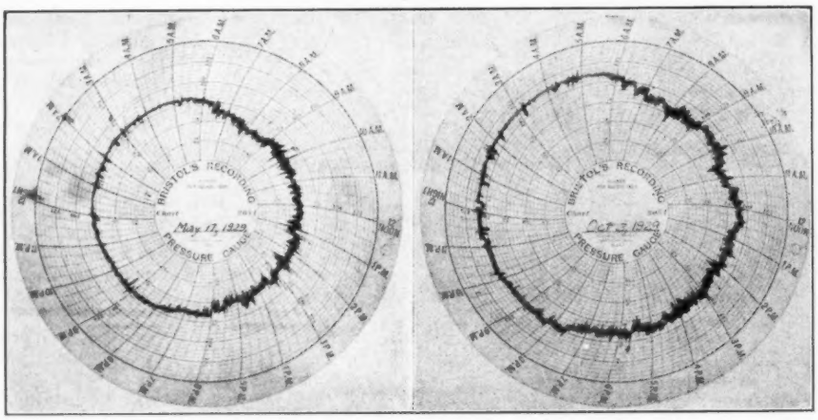
The location and repair of all leaks large enough to warrant the expense of the repair brings about important reductions in the cost of water service. It is usually the case, in fact, that the cost of the survey is covered by such reduction within a few months or a year.

A leak properly repaired is permanently closed, and the loss of water is eliminated at that point. However, in water works systems leaks are forever occurring. From some the water rises to the surface; and these leaks are at once repaired; but many do not manifest themselves and again the daily pumpage increases.

A Pitometer survey must not be considered as a leak prevention undertaking. New leaks may follow the survey, but at small expense periodical remeasurements of the district will indicate where such have developed. In some of the larger cities five year programs have been instituted. These programs which cover some portions of the system each year have yielded very satisfactory results, both from the operating and economic points of view.



A Photo-Recorder Set-up on the Job



An Advantage of Leak Correction Illustrated
Frequently an important consideration is the recovery of pressures on the system as the result of leakage surveys and correction. These two pressure record charts (before and after), taken at an outlying point on the system, require no further explanation. Hidden in this record is that of reduced pumping costs in maintaining pressures, as well as in reduced volume pumped.

WATER WASTE DETECTION BY OBSERVING SEWER FLOWS

By D. D. GROSS, Chief Engineer
Board of Water Commissioners
Denver, Colorado

COLORADO'S pioneers came looking for gold, but stayed to learn that when the welfare of man is considered, water is more valuable even than the glittering nuggets which spelled wealth to the fortunate.

The gold-rush with the famous slogan "Pike's Peak or Bust," resulting in the founding of Denver and the settlement of Colorado, started in 1858. As Colorado grew the demand for water grew and as the demand for water grew the laws governing the use of water grew. The water laws provide that "the first in use is the first in right" to water flowing in Colorado streams. As the requirements of water for irrigation developed faster than the requirement of water for municipal purposes, Denver found it necessary to buy rights to *the use of water*, which implied its return to the streams.

The Importance of Returned Water—Sewage

There seemed to be a policy on the part of irrigation interests to institute litigation to prevent Denver from obtaining more of the direct river flow. It became very important therefore that Denver have available complete and accurate information as to the per cent of water that was returned to the river through the sewers, as well as a record of that taken into the water supply system.

In Colorado we do not consider it good form to talk about the *consumption* of water; it is better to say the *use* of water, fostering the thought that after use much of it is returned to the river. So, we must consider two kinds of water—"new" and "used."

To get at the facts as to the per cent of water used in Denver that was returned to the river we began in 1926 the keeping of records showing the flow of water through the sewers. Charts are prepared on which are shown the use of water in the city. That is the flow of water as metered in the supply conduits, and this flow corrected for loss or gain in the city distribution reservoirs. On the same charts are plotted the amount of flows in the sanitary sewers. This information is computed and plotted for two-hour periods throughout the 24 hours of the day and continually throughout the year.

What Was Learned from the Records

By a study of the charts, such as that here reproduced, over a long period of time we learned that when water was not being used for lawn sprinkling or similar use not capable of return through the sewers, that 95% of the water used was being returned through the sewers. We take this as evidence that there was very little loss of water through leakage in the city pipe system as the ratio of "used" water to "new" water remained fairly constant as the use of water increased or decreased.

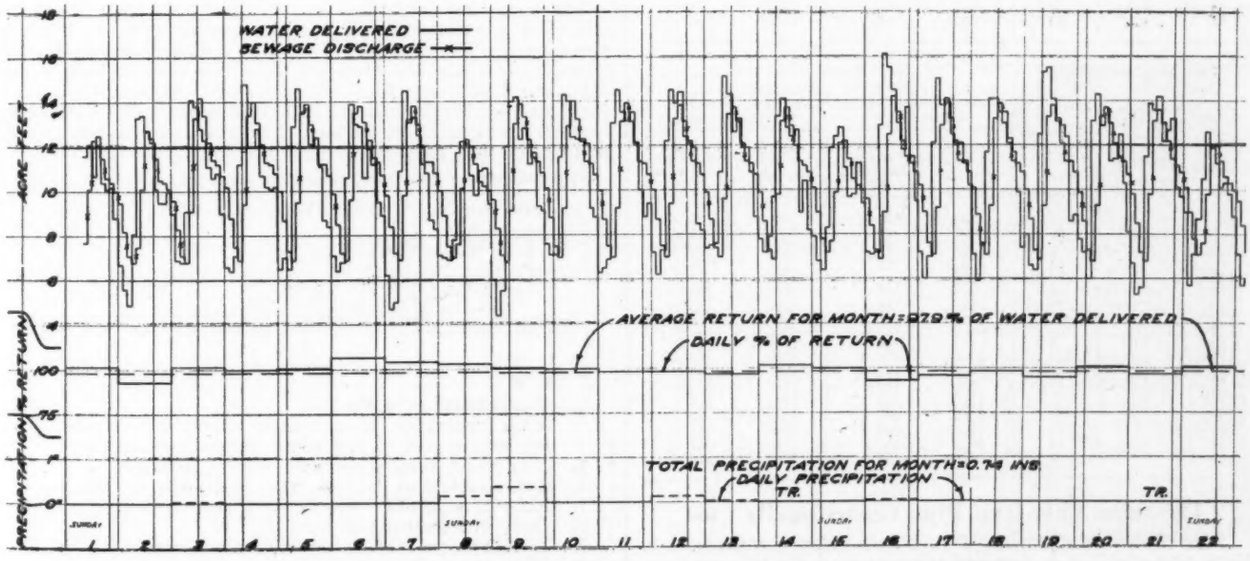
Our experience over a period of years convinces us that both the sewers and water mains are tight, with very little infiltration (say 10%) of ground water into the sewers and very little leakage from the city water mains. When leaks develop in the mains or services the water usually comes to the surface and is detected. However such is frequently not the case and leaks enter somewhere.

A few years ago when we had a cycle of dry years, necessitating a publicity campaign asking the people to conserve water and avoid waste, there was a noticeable reduction in the flow in the sewers. The same condition is observed when an extensive campaign of house-to-house inspection of plumbing is made.

Possibilities of the Scheme and a Plan

At the suggestion of Mr. L. H. Enslow, Editor of WATER WORKS AND SEWERAGE, we decided to make still further use of our sewer gaugings to determine or detect the improper use of water (water theft) in addition to tracing possible hidden leakage of moment.

Under this plan men are sent to inspect sewer manholes for unusual flow of water. We have constantly on duty men we term "servicemen." They are provided with pick-up trucks equipped with radio, maps and tools. It is their duty to respond to all important fires, operate valves, locate leaks, post red lights, etc. At headquarters we have a foreman and two or more men always on duty. If all the men are away from headquarters it is possible for the foreman to get in touch with any one of them at any time as the police department broadcasts our messages. When not otherwise engaged the servicemen do this work. They inspect the manholes at the points where the smallest laterals discharge into the branch sewers. Most of these laterals are from one to three blocks long. No attempt is made to measure the flow. The serviceman observes the amount and makes a notation as "low," "medium" or "high," to designate the amount of flow as compared to the flow in other laterals. These notes are compared when the inspection is repeated. The best time to make inspections for water wastes has been found to be between 2:00 a. m. and 4:00 a. m. At that time the regular flow is at a minimum and any unusual flow is more readily detected. If an unusual flow is discovered at night, an order is given the day servicemen the next morning to make house-to-house inspections and find where the water is coming from.



A Portion of the Water Supply and Sewage Discharge Record for January, 1939
(Note that sewage flows lag behind water use rates by roughly two hours. Note also that sewage flow for month averages almost 98% of water supplied distribution system in a month of negligible infiltration expectancy.)

UNITED STATES PIPE AND FOUNDRY CO.

General Offices: Burlington, New Jersey

SALES OFFICES

Philadelphia, New York · Birmingham, Chicago · San Francisco, Boston · Pittsburgh, Buffalo · Cleveland, Kansas City · Minneapolis, Dallas · Seattle, Los Angeles

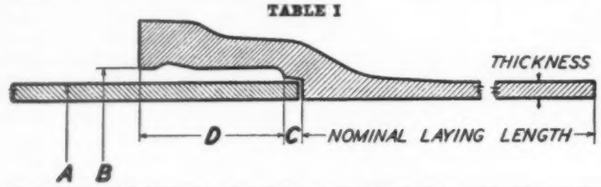
Makers of

SUPER-DE LAVAUD CENTRIFUGALLY CAST IRON PIPE
PIT CAST IRON PIPE AND FITTINGS
THREADED PIPE IN IRON PIPE SIZES
WEBRE INDUSTRIAL AND SUGAR APPARATUS
USICAST CHEMICAL CASTINGS
U. S. JOINT PIPE AND FITTINGS
FLANGED PIPE AND FITTINGS
FLEXIBLE JOINT PIPE
LARGE CASTINGS TO ORDER
USICAST CAST IRON ROOF

Super-deLavaud Pipe with B&S Joints

Super-deLavaud Pipe with bell and spigot joints is available in all sizes from 3" to 24" and in 12-foot and 18-foot lengths. The joint is particularly adaptable for lead, cement, joint compound or rubber ring assembly. The centering ring insures easy alignment and uniform distribution of the jointing material. The process by which this pipe is produced assures concentricity, evenness of metal and freedom from sand or slag inclusions. The bell and spigot joint, made with lead or other jointing materials, shows ample strength to resist pulling apart. If required to meet service conditions, pipe will be furnished with special linings. All Super-deLavaud Pipe with bell and spigot joints are made to meet Federal Specification WW-P-421. Write for descriptive booklet.

TABLE I



Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length: 12-Foot Length, Weight of Pipe Pounds	12-Foot Length, Weight Per Foot Including Bell	18-Foot Length, Weight of Pipe Pounds	18-Foot Length, Weight Per Foot Including Bell
3	150	.33	140	11.8	210	11.7
3	250	.36	155	12.8	230	12.7
4	150	.34	195	16.4	285	15.9
4	250	.38	220	18.4	325	17.9
6	150	.37	315	26.3	460	25.5
6	250	.43	350	29.3	515	28.5
8	150	.42	475	39.4	690	38.3
8	200	.46	510	42.4	745	41.3
8	250	.50	545	45.5	800	44.3
10	150	.47	640	53.3	935	51.8
10	200	.52	700	58.3	1025	56.8
10	250	.57	760	63.3	1115	61.9
12	150	.50	810	67.4	1180	65.6
12	200	.57	905	75.4	1325	73.7
12	250	.62	990	82.5	1450	80.7

Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length: 12-Foot Length, Weight of Pipe Pounds	12-Foot Length, Weight Per Foot Including Bell	18-Foot Length, Weight of Pipe Pounds	18-Foot Length, Weight Per Foot Including Bell
14	100	.48	920	76.5	1340	74.3
14	150	.55	1060	88.5	1555	86.3
14	200	.62	1190	99.0	1735	96.3
14	250	.69	1320	110.0	1930	107.3
16	100	.52	1130	94.2	1645	91.4
16	150	.60	1320	110.2	1935	107.4
16	200	.68	1490	124.1	2175	120.7
16	250	.75	1635	136.1	2390	132.7
18	100	.56	1365	113.8	1990	110.6
18	150	.65	1595	132.8	2330	129.6
18	200	.74	1810	150.9	2645	146.9
18	250	.83	2015	168.0	2950	163.9
20	100	.58	1585	132.0	2305	128.0
20	150	.68	1860	155.0	2720	151.0
20	200	.78	2125	177.1	3105	172.4
20	250	.88	2365	197.1	3465	192.4
24	100	.64	2085	173.8	3035	168.6
24	150	.76	2480	206.8	3630	201.6
24	200	.88	2855	237.8	4170	231.6
24	250	1.00	3200	266.8	4690	260.6

Threaded Cast Iron Pipe Centrifugally Cast

Super-deLavaud Cast Iron Pipe is now being manufactured in "iron pipe sizes" with threaded joints to meet the demand for a better and more durable pipe. There are two distinct types of service for which Super-deLavaud Cast Iron Pipe may be used: pressure service for water, gas, steam or similar liquids and gases; and drainage service. Pressure pipe is made to meet the requirements of Federal Specifications WW-P-421 and is supplied in three classes: standard, extra-strong and double-extra-strong. Drainage pipe, used for waste, vent and drain work, is a lighter pipe for use in buildings and elsewhere where a tight screw-coupled joint is needed. Drainage pipe is made to meet the requirements of Federal Specifications WW-P-356.

THREADED CAST IRON PRESSURE PIPE

(Made to meet the requirements of Federal Specifications WW-P-421)

Size Inches	Class	Nominal Length, Feet	Outside Diameter, Inches	Nominal Thickness, Inches	Threads per Inch	Weight per Foot Pounds
3	Standard	12	3.50	.36	8	11.08
	X-strong	12	3.50	.45	8	13.45
	XX-strong	12	3.50	.48	8	14.21
4	Standard	18	4.50	.38	8	15.34
	X-strong	18	4.50	.48	8	18.91
	XX-strong	18	4.50	.52	8	20.29
5	Standard	18	5.56	.40	8	20.22
	X-strong	18	5.56	.49	8	24.40
	XX-strong	18	5.56	.53	8	26.15
6	Standard	18	6.63	.43	8	26.13
	X-strong	18	6.63	.51	8	30.59
	XX-strong	18	6.63	.55	8	32.78
8	Standard	18	8.63	.50	8	39.85
	X-strong	18	8.63	.56	8	44.29
	XX-strong	18	8.63	.60	8	47.22

THREADED CAST IRON DRAIN PIPE

For Waste, Vent and Drainage Service

(Made to meet the requirements of Federal Specifications WW-P-356)

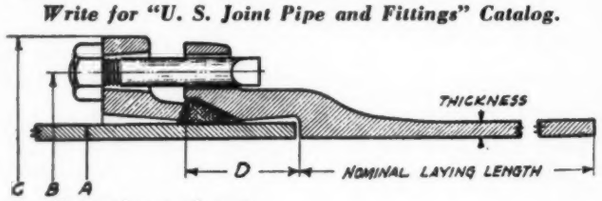
Size Inches	Nominal Length Feet	Outside Diameter Inches	Minimum Thickness Inches	Threads per Inch	Weight per Foot Pounds
3	12	3.50	.26	8	9.41
4	18	4.50	.29	8	13.75
5	18	5.56	.33	8	19.05
6	18	6.62	.38	8	26.22
8	18	8.62	.44	8	39.82

THE U. S. JOINT

The U. S. Joint embodies the more favorable features of certain other types of mechanical joints and was developed and patented by the United States Pipe and Foundry Company after considerable study and research. It is adaptable to both Super deLavaud Centrifugal Pipe, and to pit cast pipe and fittings and these may be interchanged one with another in the laying of a line without the need of an adapter. The accessories, which consist of follower ring, gaskets and bolts are all interchangeable.

It possesses the following salient advantages:

Write for "U. S. Joint Pipe and Fittings" Catalog.



1. Ruggedness of parts.
2. High resistance to corrosion since all of the joint accessories are of the same material—cast iron.
3. Maximum joint deflection without leakage.
4. Great resistance to the flow of electric currents.
5. Ease of assembly—needs only one wrench.
6. Only one gasket per joint.
7. Excellent qualities as an expansion joint.
8. Tightness under high pressures of gas or water.
9. Connection to plain end existing pipe line without use of adapter.

HYDRAULIC DEVELOPMENT CORPORATION

MANUFACTURERS OF HYDRO-TITE—A SELF-CAULKING COMPOUND FOR JOINTING CAST IRON WATER MAINS

MAIN SALES OFFICE:
50 CHURCH ST., NEW YORK, N. Y.

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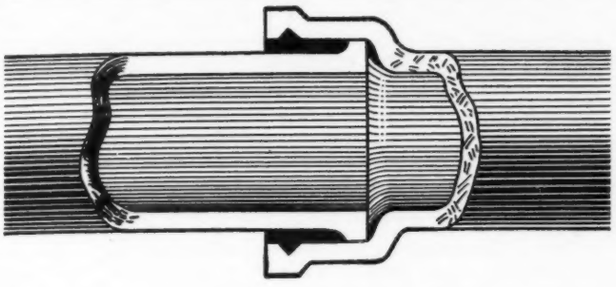
A Symbol of Quality



HYDRO-TITE does not shrink when cooling but makes a solid bond the entire depth of joint.

Other HYDRO-TITE Features

Self-Caulking: HYDRO-TITE is melted by a small fire and nothing is added to make it liquid. When poured into a joint it immediately solidifies upon contact with the metal and bonds to both the surfaces of the bell and the spigot for the entire length of the joint. HYDRO-TITE requires no caulking.

Self-Sealing: HYDRO-TITE joints are, under normal conditions, perfectly tight when pressure is first applied. Any leak or seep from a new joint will soon be stopped by the self-sealing quality of HYDRO-TITE. Even leaks occurring when pouring over-heated HYDRO-TITE will seal themselves within a day or two. "Less leakage from the start and quicker sealing qualities in case of small leakage."

Ready for Immediate Use: There need be no waiting time after pouring a joint with HYDRO-TITE. It solidifies at once upon contact with the pipe and is ready for regular pipe service.

Resists Vibration: HYDRO-TITE can be used anywhere. It is in service on pipe lines carried over bridges subjected to heavy automobile trucking, trolley cars and continuous railway traffic.

Strength to Support Joints: Flood washouts have many times left entirely unsupported several sections of large pipe and without any leaky joints resulting. In one case, at Fitchburg, Mass., a 30" class B main weighing 4000 pounds was entirely supported from the bell end by the HYDRO-TITE joint after the false work supporting the spigot end had been washed away.

Approved by

HYDRO-TITE is approved and used by leading engineers, municipal water works, water companies, railroads, mines and industrial plants throughout this country and many others. It is also approved by the Associated Factory Mutual Insurance Companies and will be found listed on page 5, their "Rules for Laying Cast-Iron Pipe," issued June, 1929.

Properties of HYDRO-TITE

HYDRO-TITE is a black powder composed of selected inert minerals. When melted and allowed to cool, it becomes a strong, tough, metallic mass. Compressive strength is 6000 lbs. per square inch and its tensile strength is over 650 lbs. per square inch.

Manufacture of HYDRO-TITE

HYDRO-TITE is made in an up-to-date factory with modern machines and by efficient methods. Constant inspection, alert supervision and many years of research by some of the best trained chemical scientists combine to make HYDRO-TITE the leader in its field. This makes possible our continued use of the slogan—"MORE THAN 30 YEARS WITHOUT A FAILURE."

Packing and Shipping

HYDRO-TITE is packed and shipped in 100-lb. heavy burlap bags. Each bag contains a specially treated moisture-proof liner which keeps the HYDRO-TITE dry even though stored in a damp place or transported in the rain.

Other Products

Braided Jute

Yarning Irons

Yarning Hammers

Joint Cutters

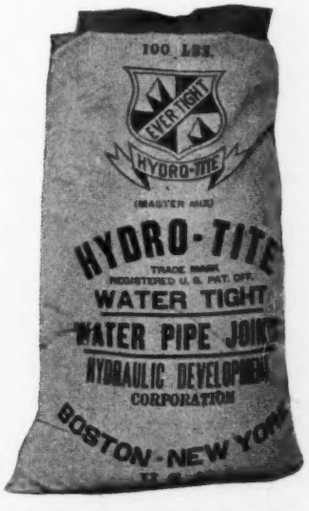
Joint Runners

Open Seam Pouring Funnels

Wood-Burning Furnaces

Pouring Pots

Pouring Ladles



OVER 30 YEARS IN SERVICE WITHOUT A SINGLE FAILURE

ESTIMATING THE COST OF MAINS

And the Setting Up of a Useful Estimating Guide Chart

By D. R. TAYLOR
Plant Superintendent
Roanoke Water Department, Roanoke, Virginia

AMONGST the vicissitudes and pleasures of life and the progress of industry and commerce, prognostication continues to be increasingly interesting to most of us. As time goes on, our material and cost estimates, like mathematical formulæ involving infinity, continue to approach something that they may never actually reach—namely, factual perfection.

Even the average life span of such an everyday thing as cast-iron pipe is still a matter of conjecture. Authentic records of the earliest cast-iron pipe still in service include that supplying water to a fountain at Langensalza, Germany, which was laid prior to 1562, and cast-iron pipes are still supplying the fountains of Versailles, France, after 276 years of service. There are many records going back over 150 years in England and more than 100 years in this country. Such records as these have often been the cause of much difference of opinion among engineers in the appraisal of the net worth of water plants.

Estimating the Cost of Mains and Extensions

The accompanying tabulation has been prepared by the writer for use as a handy reference in estimating. It is based on the average cost of mains under an average group of conditions and methods. Considering that each of the sixty-six items, making up the aggregate, vary according to varying conditions and methods, it may be easily appreciated that, any number of combinations of these items may influence the end result in accurate estimating.

Some of the items shown may be performed at a lower cost than indicated, while others may cost more. As a matter of fact, methods and costs will undoubtedly vary between jobs in the same locality; however, the fact remains that an estimate is necessarily based on an average of as many representative jobs as can be reviewed at the moment.

While there are many very reliable records of total costs of mains, it is surprising what little information can be obtained relative to the man hours and equipment hours required to perform the individual items comprising the total job.

Applying Correction Factors

These man and equipment hour units are shown for the more variable items to enable anyone to calculate an estimate of his costs by substituting his prevailing labor and equipment prices in deriving required correction factors. It is, of course, understood that prices of materials will vary between times and places, especially cast-iron pipe, and it is assumed that quotations on these will be obtained in each specific instance, and a correction factor derived for application.

rially less than that of "standard" pipes specified and used in former years.

As times goes on and more records and improved equipment become available, undoubtedly modifications and adjustments will

In the case of cast iron pipe of sizes 30 inches and larger, the manufacturers will send their representatives to inspect the site of the proposed project and design lighter but higher tensile strength pipe to suit the particular conditions such as depth of cover and weight and intensity of traffic. Such pipe now obtainable through modern methods can be furnished at prices matebe suggested. In the meantime, accumulating cost records should be extremely interesting and the accompanying table should serve a useful purpose in arriving at more dependable cost data in water main construction, which will be highly useful in setting up estimates.

Note—This tabulation of estimating data constitutes a material amplification of an earlier tabulation used by Mr. Taylor and reproduced in the 1940 *Reference and Data Number of this magazine. In his successful attempt to better the original tabulations the following excerpts from Taylor's letter are significant.*

"During the last two years I have talked with a great many contractors, engineers and water works operators and have been surprised to learn that none of them knew the unit man and equipment hours required to perform the various items in laying mains.

"During the last year we have been doing some unit accounting in all of our construction and maintenance work in an effort to determine these units, with the idea of making a tabulation with which any operator in any city or town could substitute his labor and equipment costs and calculate an estimate of the cost of mains. In addition to this, I wrote the pipe manufacturers for such information as they might have. Such proved to be practically nothing.

"In discussing the matter and exchanging experiences with others, they said if I succeeded in working out a tabulation of units, that it would be a real contribution.

"Considering this a challenge, I began collecting information from equipment manufacturers, our records, the records of the city street repair department and state W.P.A. records, and slipped a slide rule at night and during week-ends for the last ninety days, and wound up with the enclosed tabulation, which may not be perfect by any means, but at any rate it is a start and the only thing of its kind that I know of in this country."—D.R.T.

To Stop Pipe Sweating*

The following formula, directions for application, and specifications for materials required in the application of an insulating protective coating for stopping troublesome sweat formation on pipes, pumps, small tanks, etc., has proved highly satisfactory according to Chas. P. Hoover, Consulting Chemical Engineer and 1st Ass't. Superintendent of Water Works at Columbus, Ohio.

Application Procedure

All surfaces must be absolutely clean and dry before any applications are made. The outside surface is first painted with a thick coat of adhesive (specified herein), after which a thick coat of ground cork is either blown or pressed on by hand. This ground cork must be built up to a uniform thickness on all exposed surfaces. After this application is thoroughly dry, a second thick coat of adhesive is applied, after which the second thick layer of ground cork is either blown or pressed on by hand. The second layer of ground cork must also be built up to a uniform thickness. After the second application is thoroughly dry, it is covered with two coats of an approved paint.

*By Chas. P. Hoover, Principal Ass't Superintendent, Division of Water, Columbus, Ohio.

The Adhesive

The adhesive is made up of the following materials:

Ingredients	*Proportions*
Whiting, dry	7¾ lbs.
Interior Varnish	4¼ lbs.
Raw Linseed Oil	¼ lb.
Paint Dryer	¼ lb.

Cork Specifications

In purchasing the cork to be used the following specifications will be found helpful:

The cork shall be equal in quality to 8/14 granulated cork as manufactured by the Armstrong Cork Co., Lancaster, Pa. It shall be ground so that not less than 95% by weight of the particles will pass through a No. 8 U. S. standard sieve and not more than 5% by weight will pass through a No. 14 U. S. standard sieve. The cork shall not weigh more than 8 lbs. per cubic foot. The cork shall contain not more than 1.5% of dirt, dust, or other foreign matter.

It is to be noted that all of the above, with slight changes in a word here and there, will produce a complete specification for materials as well as the method of application should the insulating job be let to contract.

ESTIMATE OF COST OF MAINS PER FOOT

		GALVANIZED			CAST IRON											
1	Size of main	1"	1½"	2"	2"	4"	6"	8"	10"	12"	16"	18"	20"	24"	30"	36"
2	Trench-width	18"	18"	18"	20"	20"	20"	22"	24"	26"	30"	34"	36"	41"	46"	52"
3	depth	38"	38"	39"	40"	48"	52"	54"	56"	58"	64"	68"	71"	77"	86"	93"
4	Cover over bells	37"	37"	37"	36"	40"	41"	41"	41"	41"	42"	44"	44"	46"	48"	48"
5	MATERIALS—plus 1% for waste															
6	Pipe (cast iron F.O.B. siding)	.12	.14	.18	.26	.55	.80	1.13	1.52	1.95	2.99	3.60	4.20	5.60	7.83	10.67
7	Add-for cement lining				.02	.04	.07	.10	.13	.17	.19	.23	.26	.35	.40	.55
8	Add-for bitumastic lining				.03	.06	.08	.12	.16	.21	.24	.29	.31	.45	.64	.87
9	Haul pipe—up to one mile															
10	Crane & operator-hrs. per 100 ft. (one at ea. end of haul)											2.34	2.68	3.12	3.75	4.16
11	Truck & driver-hrs. per 100 ft. (two of each)				.184	.430	.750	1.140	1.560	2.040	3.120	2.34	2.68	3.12	3.75	4.16
12	Man hours per 100 feet				.750	1.700	3.000	4.600	6.300	8.400	12.500	4.68	5.36	6.24	7.50	8.32
13	COST—Crane & operator at $3.00 per hr											.0702	.0804	.0936	.1125	.1248
14	—Truck & driver at $0.75 per hr				.0014	.0032	.0056	.0086	.0117	.0153	.0234	.0176	.0201	.0234	.0281	.0312
15	—Labor at $0.38 per hr				.0029	.0065	.0114	.0175	.0240	.0320	.0475	.0178	.0204	.0237	.0285	.0316
16	Add 2% to lines 13, 14, & 15 for each extra mile															
17	Joint compound at $0.12 per pound					.0220	.0330	.0440	.0550	.0660	.0907	.1017	.1155	.1430	.1760	.2090
18	Braided hemp at $0.20 per pound					.0017	.0025	.0032	.0037	.0044	.0057	.0064	.0070	.0082	.0200	.0241
19	PAVEMENT—square yards per linear foot	.1666	.1666	.1666	.1855	.1855	.1855	.2032	.2222	.2400	.2780	.3142	.3332	.3800	.4260	.4830
20	Removal-compressor & two paving breakers															
21	Asphalt 8"—Equipment at 20 sq. yds. & $0.85 per hr	.0071	.0071	.0071	.0079	.0079	.0079	.0086	.0095	.0102	.0118	.0134	.0142	.0162	.0181	.0205
22	—Labor at 2. 5 sq. yds. & $0.38 per hr	.0253	.0253	.0253	.0282	.0282	.0282	.0309	.0338	.0365	.0423	.0478	.0507	.0578	.0648	.0735
23	Concrete 8"—Equipment at 5.0 sq. yds. & $0.85 per hr	.0283	.0283	.0283	.0315	.0315	.0315	.0346	.0378	.0408	.0473	.0535	.0566	.0646	.0724	.0821
24	—Labor at 1.25 sq. yds. & $0.38 per hr	.0533	.0533	.0533	.0594	.0594	.0594	.0651	.0712	.0767	.0890	.1008	.1066	.1215	.1362	.1542
25	Brick on 6" concrete—Equip. at 4.0 sq. yds. & $0.85 per hr.	.0353	.0353	.0353	.0393	.0393	.0393	.0431	.0472	.0508	.0590	.0667	.0706	.0805	.0902	.1022
26	—Labor at 1.0 sq. yds. & $0.38 per hr.	.0633	.0633	.0633	.0705	.0705	.0705	.0772	.0845	.0912	.1058	.1095	.1268	.1442	.1620	.1835
27	EXCAVATION—cubic yards per linear foot															
28	Entire depth	.1760	.1760	.1810	.2060	.2470	.2680	.3050	.3460	.3880	.4950	.5930	.6600	.8150	1.0200	1.2400
29	Under 8" asphalt or concrete	.1390	.1390	.1440	.1650	.2060	.2270	.2600	.2960	.3350	.4330	.5230	.5860	.7300	.9250	1.1330
30	Under brick on 6" concrete	.1252	.1252	.1302	.1493	.1903	.2113	.2428	.2780	.3146	.4100	.4970	.5580	.6985	.8900	1.0925
31	COST—by hand at .375 cu. yds. & $0.38 per hr															
32	Line 28—earth	.1782	.1782	.1835	.2087	.2501	.2718	.3090	.3509	.3930	.5020	.6010	.6690	.8260	1.0340	1.2580
33	Line 29—earth	.1410	.1410	.1460	.1672	.2088	.2300	.2635	.3000	.3399	.4380	.5300	.5940	.7400	.9370	1.1500
34	Line 30—earth	.1270	.1270	.1320	.1514	.1930	.2140	.2460	.2820	.3190	.4160	.5040	.5660	.7080	.9020	1.1090
35	Medium soft shale at $2.25 per cubic yard (line 28)	.3960	.3960	.4075	.4640	.5560	.6030	.6860	.7780	.8730	1.1140	1.3340	1.4860	1.8340	2.2940	2.7900
36	COST—by machine, operator, helper, & three laborers at 25															
37	cu. yds. & $7.60 per hr															
38	Line 28—earth only or earth & asphalt	.0535	.0535	.0550	.0626	.0751	.0815	.0927	.1051	.1180	.1502	.1801	.2008	.2478	.3100	.3770
39	Line 29 & 30 after concrete & brick removed	.0423	.0423	.0437	.0502	.0626	.0690	.0790	.0900	.1019	.1315	.1590	.1780	.2220	.2810	.3444
40	Hard rock-equipment, materials & labor at 0.5 cu. yds. &															
41	$1.60 per hr. (line 28)	.5630	.5630	.5780	.6590	.7900	.8570	.9760	1.1080	1.2410	1.5820	1.8980	2.1100	2.6100	3.2600	3.9680
42	Add for bracing-to lines 32, 33, 34, 33 & 39									.09	.10	.11	.12	.13	.14	.15
43	LAY PIPE—crane & operator-hrs. per 100 feet											2.78	3.46	3.88	4.30	4.68
44	—man hours per 100 feet	5.270	5.270	5.270	5.270	18.40	23.70	26.30	31.60	36.80	44.70	19.50	24.20	27.20	30.10	32.80
45	COST—crane & operator at $3.00 per hr											.0834	.1038	.1164	.1290	.1408
46	—labor at $0.38 per hr	.020	.020	.020	.020	.070	.090	.100	.120	.140	.170	.0742	.0920	.1032	.1188	.1245
47	BACKFILL—entire depth—cubic yards per foot	.1584	.1584	.1629	.1854	.2223	.2412	.2745	.3114	.3492	.4340	.5160	.5660	.6800	.8100	.9470
48	COST—by hand at 1.0 cu. yd. & $0.38 per hr	.0602	.0602	.0618	.0705	.0845	.0916	.1042	.1182	.1328	.1650	.1960	.2150	.2582	.3080	.3220
49	—by machine, operator & four laborers															
50	—at 25 cu. yds. & $3.52 per hr	.0223	.0230	.0229	.0262	.0314	.0340	.0387	.0439	.0493	.0612	.0727	.0798	.0960	.1142	.1335
51	TAMPING—by hand at 0.666 cu. yds. & $0.38 per hr. (line 47)	.0905	.0905	.0928	.1058	.1270	.1375	.1565	.1775	.1990	.2472	.2940	.3228	.3880	.4620	.5400
52	—by machine—one compressor & five tampers															
53	—equipment at 10 cu. yds. & $0.85 per hr	.0135	.0135	.0138	.0158	.0189	.0205	.0234	.0264	.0297	.0369	.0438	.0481	.0578	.0688	.0720
54	—labor & 2.0 cu. yds. & $0.38 per hr	.0301	.0301	.0309	.0352	.0423	.0458	.0522	.0592	.0664	.0825	.0980	.1075	.1292	.1540	.1800
55	SURPLUS—cubic yards per linear foot	.0176	.0176	.0181	.0206	.0247	.0268	.0305	.0346	.0388	.0610	.0770	.0940	.1350	.2100	.2930
56	COST of disposal at $0.75 per cu. yd	.0132	.0132	.0136	.0155	.0186	.0206	.0229	.0260	.0291	.0457	.0577	.0705	.1012	.1575	.2200
57	PAVEMENT—cost of restoration (line 19)															
58	Asphalt 8"—at $1.25 per sq. yd	.2082	.2082	.2082	.2320	.2320	.2320	.2540	.2780	.3000	.3480	.3930	.4170	.4750	.5320	.6040
59	Concrete 8"—at $4.00 per sq. yd	.6660	.6660	.6660	.7420	.7420	.7420	.8130	.8900	.9600	.1112	.1260	.1332	.1520	.1702	.1930
60	Brick on 6" concrete—at $5.00 per sq. yd	.8330	.8330	.8330	.9270	.9270	.9270	1.0150	1.1120	1.2000	1.3900	1.5720	1.6660	1.9000	2.1300	2.4100
61	COST of connection at intersection (see line 64)	.65	1.00	1.50	3.00	10.00	14.00	20.00	27.00	34.00	47.00	57.00	68.00	95.00	158.00	268.00
62	COST of valves with small boxes (see line 64)	6.50	9.00	12.50	12.50	18.00	27.00	39.00	61.00	78.00						
63	COST of valves vaulted with brick (see line 64)					30.00	39.00	55.00	78.00	97.00	270.00	350.00	427.00	593.00	918.00	1390.00
64	Multiply number of each by unit cost and divide by length in feet for cost per foot															
65	Treat specials as in line 64															
66	Add 10% for supervision and small tools—5% for work in intermediate sections & 10% for congested sections															

These tabulations do not include fire hydrants, office overheads, engineering, fixed charges, insurance, first aid, etc. Units and costs are based on using workers and laborers experienced in water works construction. For inexperienced workers and common labor the units will be somewhat lower and costs per foot somewhat higher. Units and costs are also based on best conditions in outlying partially built up sections. For mains in open country make proper adjustments of items affected. Backfill based on total depth with street opened to traffic and paving done somewhat later. If paving is to be done along with job, make proper adjustments of items affected. For small jobs during which men assemble at shop and are transported on department time, make proper adjustments of labor costs. Roughly each half hour so consumed adds 6% to labor costs, although other advantages may offset this added cost depending upon number of men involved.—D. R. TAYLOR, Roanoke, Va.

TRANSPORTATION SIMPLIFIED

Power Crane-Equipped Truck Makes for Ease and Economy

By D. R. TAYLOR
Plant Superintendent
Water Department, Roanoke, Virginia

THE problem of transportation is one that many of us were confronted with when we began using cast iron pipe 18 feet long. If you have much hauling to do, it will pay you to buy a long wheel-base truck chassis and to have a power crane installed on it and have a platform body built locally to meet your particular needs. Such a truck chassis that we purchased and equipped when we began the use of 18 foot pipe is here pictured. The power crane was obtained from the Baker Equipment Corp., Richmond, Va., who are our nearest agents for the Gar Wood Industries of Detroit.

The truck chassis should have a wheel base of at least 220 inches. The dimensions of our particular piece of equipment are as follows: The length from the back of the cab to the end of the frame is 19 feet. The crane utilizes 3 feet of this space, and our platform body is 17 feet long, allowing the body to project 1 foot beyond the end of the frame. This allows 18 foot pipe to project 1 foot beyond the body with a total overhang of 2 feet beyond the end of the frame. This is permissible and within the bounds of good practice, as recommended by truck manufacturers. For flexibility and economic transportation, I would suggest that you purchase a heavy duty two-ton chassis, with which you can easily haul a load of four tons from your pipe lot to the job in question without abusing the equipment.

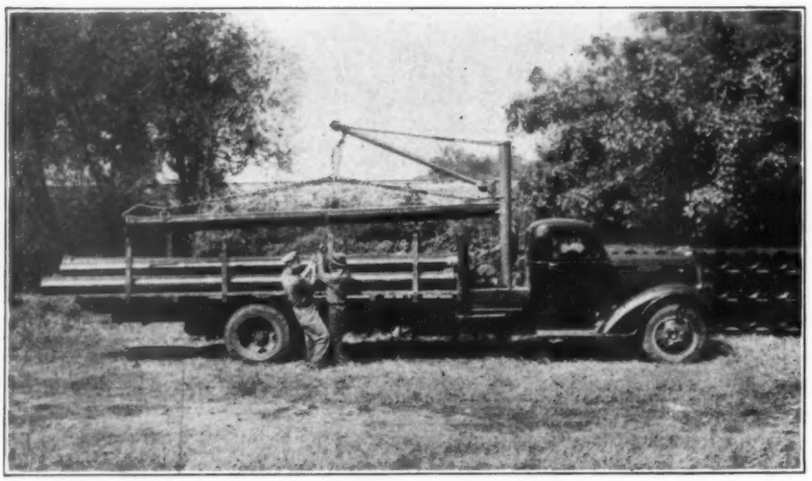
The smaller picture better shows the chain sling with a hook on each end. This was improvised by one of our foremen. The jack, shown in the foreground folded up underneath the crane platform, is one of two furnished with the crane. The jack on the side from which you are raising or lowering the load is unhooked and allowed to swing down to the ground to support the platform while you are loading or unloading.

This crane can be obtained with various capacities and booms of several lengths. I would suggest that you purchase one of 3000 pounds capacity with a 10-foot boom. It may be of interest also to you to learn that the mast and boom is demountable and can be easily removed when not needed.

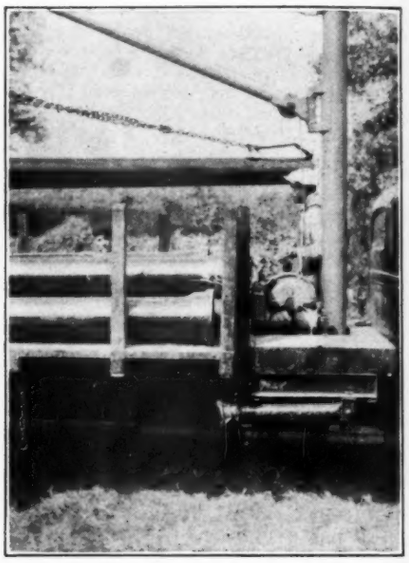
In the good old days, it required six men to unload a car of 8-inch pipe, but, with the outfit described above, three men can do the same job and do it quicker.

If interested in such a purchase and wish any more information, the writer will be glad to give it.

• • •



To Load 18-ft. Lengths of 8-in. Cast Iron Pipe With This Rig Is a Cinch



A Close-Up View Showing Power Crane, the Sling and One of the Support Jacks Beneath the Truck Bed

RELATIVE SIZES OF BRANCHES AND WATER MAINS

Size of Main	Number and Size of Branches Main Will Supply—Running Full
½"	Two—⅜"
¾"	Two—½"
1"	Two—¾"
1¼"	Two—1" *or* One—1" and Two—¾"
1½"	Two—1¼" *or* One—1¼" and Two—¾"
2"	Two—1½" *or* One—1½" and Two—1¼"
2½"	Two—1½" and Two—1¼" *or* One—2" and Two—1¼"
3"	One—2½" and One—2" *or* Two—2" and Two—1½"
3½"	Two—2½" *or* One—3" and One—2" *or* Four—2"
4"	One—3½" and One—2½" *or* Two—3" *or* Three—2½" and One—2" *or* Six—2"

THE ATLAS MINERAL PRODUCTS COMPANY

OF PENNSYLVANIA — MERTZTOWN, PA.

Tegul- MINERALEAD

for Jointing Bell and Spigot Water Mains

Composition

Tegul-Mineralead is a plasticized sulphur compound containing a specially-prepared olefine polysulphide as a plasticizing agent developed by a staff of Chemists, Chemical Engineers, and Civil Engineers whose services are available for recommending, designing and supervising the erection of all types of construction in which Tegul products are used.

How Used

MELTING: Tegul-Mineralead melts at 248° F., requiring only a low fire. Care should be exercised to avoid direct contact with flame and over-heating, in which case the compound tends to thicken. Best results will be obtained when using a furnace designed by the manufacturers of Tegul-Mineralead.

YARNING: The pipe at the Bell and Spigot must be clean and free from accumulations of oil, grease, dirt and tar. If Jute is used, only Dry, Braided is recommended. Sterilpak (described below) is advised because of its many advantages over ordinary yarn or jute.

POURING: See that the joints are clean. Use mud on the asbestos runner to prevent adhesion with the Tegul-Mineralead and to seal any leaks. Pour the melted compound slowly through a high pouring gate, using ladles or a pouring pot of sufficient capacity so that the joint can be filled at one operation. Add whole or half ingots to replace Tegul-Mineralead used. It is not necessary to wait for complete melting before pouring more joints. Cut off the pouring gate when the compound has solidified. Remove the runner and the joint is finished.

POURING WET JOINTS: The same general process is used as described above except that the runner must be held away from the bell at the bottom of the joint to provide an outlet through which the Tegul-Mineralead can drive out the water. When the compound flows freely through this opening, close it with clay and continue pouring until the gate is full. Better results are obtained if the Tegul-Mineralead is heated to just below the thickening point.

Advantages

Tegul-Mineralead has greater adhesion to metallic and ceramic surfaces, greater resistance to vibration, mechanical shock and changes in temperature, greater plasticity, and a lower coefficient of expansion than have unplasticized sulphur cements. Tegul-Mineralead has the following specific properties:

1. The "initial" leakage is greatly reduced and a perfectly tight joint is obtained in a shorter period of time. Thus less delay in construction and the elimination of the traffic problem caused by open trenches.
2. Greater resistance to mechanical shock and vibration enable Tegul-Mineralead to stand up under conditions that will destroy lead joints.
3. The resistance of Tegul-Mineralead to sudden changes in temperature is of importance when used in lines exposed to the elements or used for carrying hot water.
4. Permanently tight and trouble-free water line under any ordinary conditions of use.

Tegul-Mineralead is impervious to water, is convenient to handle and to store and is shipped in cartons containing five 10-lb. ingots. Every batch of Tegul-Mineralead is sampled and tested before being accepted for shipment.

STERILPAK—Rubber Packing for Yarning Bell and Spigot Joints in Cast Iron Water Mains

Sterilpak avoids the extreme difficulty often encountered in sterilizing water lines whose joints have been packed with jute or hemp. Sterilpak requires only one thorough chlorination since any bacteria present are on the surface only. Easily applied, dams off water in making wet joints, centers the pipe, economical. Supplied in round and wedge shapes.

Quantities of STERILPAK and Tegul-MINERALEAD required per joint in Bell and Spigot Cast Iron Water Pipe

Size of Pipe	Pounds Per Joint Round Sterilpak	Wedge Sterilpak	Tegul-Mineralead
4″	.29	.27	1.9
6″	.38	.36	3
8″	.48	.44	4.6
10″	.57	.54	5.5
12″	.67	.63	6.5
14″	.77	.72	7.5
16″	1.34	.88	10.1
18″	1.50	.98	11.7
20″	1.64	1.07	12.6
24″	1.95	1.27	14.9
30″	2.40	1.56	18.4
36″	2.85	1.86	22.2
42″	3.30	2.15	29.5
48″	3.76	2.45	33.3

The above quantities are approximate. The Tegul-MINERALEAD quantities will be about 20% higher if there is no bead on the spigot end of the pipe.

G-K SEWER JOINT COMPOUND—A Positive, Permanent, Pliable Pipe Joint

G-K SEWER JOINT COMPOUND is the original bituminous sewer joint. It is not affected by water, sewage, acids or the ordinary constituents of soil. Prevents infiltration, pollution of ground by leakage of sewage, and penetration of roots, such as are found in temperate climates. May be used in cold weather, remains flexible, does not require skilled labor. Successfully used for over 30 years. Shipped in 120 and 270 lb. drums.

Quantities of G-K Compound per joint:

Size of Pipe	Depth of Joint	Cubic Inches of Compound	Pounds Jute	Pounds* G-K
4″	1¼″	8.2	.03	.52
6″	1¾″	19.2	.04	1.22
8″	1¾″	31.2	.15	1.98
10″	1¾″	38.1	.26	2.42
12″	1¾″	48.2	.31	3.07
15″	1¾″	55	.40	3.5
18″	2¼″	83.7	.47	5.31
21″	2¼″	120.1	.65	7.59
24″	2¼″	136.5	.74	8.58
27″	2½″	202.2	1.29	12.87
30″	2½″	250	1 65	15.9
33″	3″	328	1.76	19.5
36″	3″	450	2.44	28.8

*This calculation is based on 10% excess for possible waste.

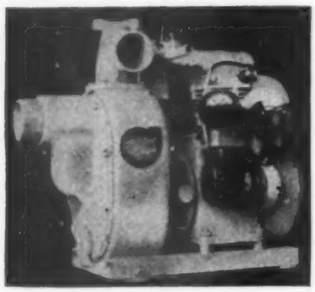
NORTHROP & COMPANY, INC.

Water Works Specialties and Supplies

50 Church Street • NEW YORK, N. Y.

Marlow Lightweight, Self-Priming Centrifugal Pumps

3,000, 7,000 and 12,000 G.P.H.



1½", 2", and 3" sizes weighing respectively only 60*, 100, and 106 lbs. (*76 lbs. with cast iron pump). Easily carried by one or two men. 25 foot vertical suction lift and will discharge against a total head of 55 ft. Powered by four cycle, air-cooled gasoline engines equipped with magneto ignition, speed changer and tapered roller bearings on crankshaft.

The pump shell is self-cleaning with open type impeller specially adapted for dirty water. A special long-wearing shaft seal replaces packing. Aluminum alloy construction.

FREE TRIAL

Two weeks' trial of any Marlow Light-Weight with full credit return if not satisfactory.

Two Wheel Mounted—7,000 to 200,000 G.P.H.

2" to 10" Marlow gasoline engine powered units are mounted upon pneumatic or steel tired trailer carts.

Pumps are equipped with trash type impellers, self-cleaning casings and special long-wearing shaft seals. Special feature allows removal of trash accumulated in the suction housing through hand hole plate without stopping engine or losing priming water. Automatic control device prevents re-circulation of water after pump is primed.

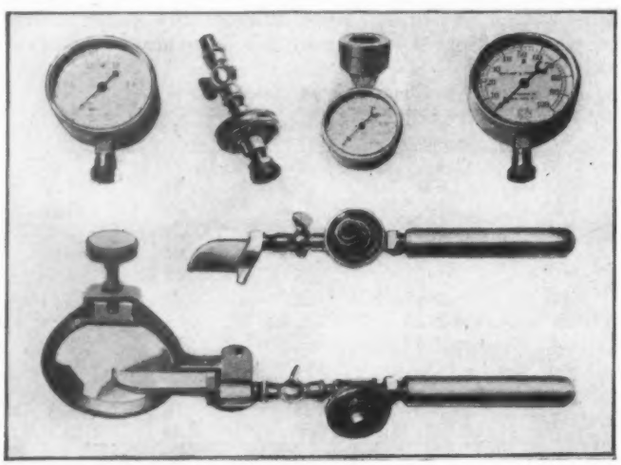
Also complete line of Marlow Diaphragm and Plunger pumps.

NORTHROP Water Works Test Sets

A complete test set for hydrant flows, pressure and loss of head. This set contains two Pitots with gauges, a faucet gauge which can also be used as a hydrant pressure gauge, and a hydrant adapter for use with the faucet gauge. All parts are chromium finished.

The gauges are manufactured to specifications furnished by the National Board of Underwriters. One gauge indicates both pounds pressure and approximate equivalent in gals. per min. when used on 2½" hydrant connections.

The Hand Pitot or Combination Hand & Clamp Pitot, each with a 2-scale gauge, may be ordered separately. These sets as well as the complete set are shipped in handsome carrying cases. Instructions for making Hydrant Discharge Measurements are enclosed.



A—Hand Pitot with Air-Chamber and Throttling Cock.

B—Combination Hand and Clamp Pitot with Air-Chamber and Throttling Cock.

C—Two-Scale Gauge for 2½" hydrant openings; lbs. pressure and gals. per min.

D—Hydrant Cap Gauge —100 or 150 lbs.

E—Faucet Gauge—100 or 150 lbs.

F—Hydrant Cap Adapter.

G—Carrying Case.

OTHER PRODUCTS

McDONALD
Brass Goods

•

SCHRAMM
Portable Compressors
Stationary Compressors
Pneumatic Tools

•

HOBART
Thawing Generator

•

TAYLOR
Slide Comparators
Water Analyzer
Color Standards

•

The "Flow-O-Meter"
Leak Locators
Pipe Finders
The Meter-Master
Air Valves
Pipe Cutters
Pipe Pushers
Repair Couplings
Steam Thawers
Gauge Testers
Meter Boxes & Yokes
Valve & Curb Boxes
Meter Testers
Meter Seals & Books
Lanterns & Torches

MAINTENANCE OF WATERWORKS EQUIPMENT*

By SHERMAN L. ROGERS, District Engineer
Water Bureau, Hartford, Conn.

Now, in the building of chaises, I'll tell you what,
There is always somewhere a weakest spot—
In hub, tire, felloe, in spring or thill,
In panel, or crossbar, or floor or sill,
Find it somewhere you must and will
And that's the reason beyond a doubt
That a chaise breaks down but doesn't wear out.

OLIVER WENDELL HOLMES wrote the above lines many years before most of our modern machinery was even thought of. The moral in the poem is still more or less true, but I think that the statement that machinery "breaks down but doesn't wear out" is slightly inaccurate.

In waterworks operation, it is most important that machinery and equipment be in best possible condition for instant use, especially emergency equipment which may be required at any moment to control or repair breaks in large pipe lines.

Emergency Truck and Tool Trailer

To control a break similar to one which occurred in a 30" cast-iron main in West Hartford last winter, we have a 1½-ton truck equipped with maps, gate locations, gate wrenches and other tools.

A gate-closing mechanism for closing down the larger valves with the truck motor is also installed on this truck. With this mechanism a 30" gate which would ordinarily take four men 30 minutes to close by hand can be closed in 10 minutes (see Fig. 1).

This particular break, in which one length of 30" pipe split from end to end, occurred at about 10 a. m. and service was completely restored within 9½ hours. To accomplish speedy repair work like this, we keep a trailer tool box at our main yard completely equipped with boots and enough hand tools to get repair work well under way. This eliminates delay while tools are being assembled from various jobs.

Compressors and Air Tools

Since a large proportion of our main streets have a concrete base, an air compressor is usually needed to break down the pavement. We have five compressors and a Barco gasoline driven paving breaker. Two of the compressors are truck-mounted portable units and three are powered from the motors of the trucks on which they are mounted. Each compressor carries two paving breakers, two clay diggers, two tampers, a sump pump, and those on main pipe work also carry air-caulking and shipping hammers.

The latest addition to our fleet of compressors is a 134-inch wheelbase Ford with the cab over the engine which also furnishes power for the compressor unit. The inside of the body is equipped with seats for the men and bins to carry various fittings used on service pipe work.

Before a system of periodic tests and checkups was inaugurated, it was a frequent occurrence to have an air tool break down when most needed, or else have the foreman complain that the compressor assigned to him was no good because it would not run two paving breakers. Each operator now brings his compressor to the shop for a four-hour inspection and checkup every fifth week. The air output is first measured on the air meter to determine its efficiency. Air consumption tests are then made on the air tools while the mechanics check over both compressor and truck engines. On power takeoff units, the speed of the compressor is also checked, since this depends on the setting of the governor and needs occasional adjustment for proper operation. Oil is changed, plugs, distributor and carburetor cleaned, and the whole outfit tightened and inspected.

Testing and Repairing Paving Breakers

The air meter is shown (Fig. 2) with a paving breaker connected for a test in the lead pot. The hose of the compressor is connected to the meter through the connection at the left in the illustration. A flat-pointed moil point is placed in the breaker and worked in the lead for 10 seconds. The air consumption in cubic feet of free air per minute is meanwhile being noted from the meter. A 2-inch penetration into the lead is required with an air consumption not exceeding 68 cu. ft. per minute. The breakers which we use were originally rated to take about 55 cu. ft. of air per minute when new, but this gradually increases with wear. When making our first tests, we found several hammers which took 80 cu. ft. or more of air per minute, or 75% of the total output of the compressor. A breaker such as this appears to do as much work as ever, but if two such breakers were connected to a 105-cu. ft. compressor something would appear to be wrong right away. Formerly it was the compressor which took the blame instead of the breakers.

Excessive air consumption can sometimes be reduced by taking the air tool apart and cleaning it, but if it has been used without oil and the cylinder is scored, or if it is badly worn, it is necessary either to install oversize pistons or have the cylinders built up by the chrome process, which is very satisfactory, and the cost is approximately half that of a new paving breaker. Oil is very important in the operation of paving breakers, and we insist that the oil reservoirs in the handles be filled at least twice a day. During cold weather, three gallons of oil are diluted with one gallon of kerosene and one gallon of alcohol. The alcohol prevents the tools from freezing and the kerosene serves to dilute the oil and makes it mix with the alcohol more readily.

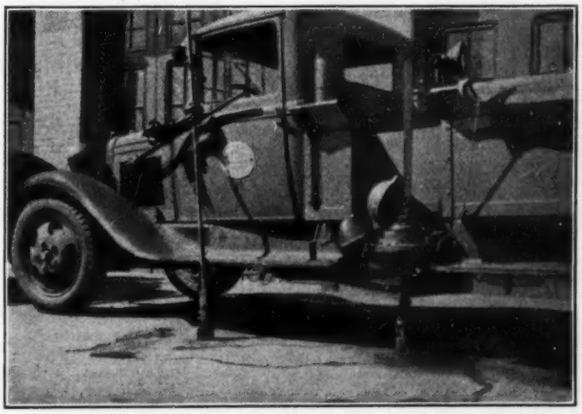
The clay diggers and tampers are given an air consumption test, while the sump pumps are tested in a tub of water. Air consumption alone is a fairly accurate indication of the amount of water a pump will lift. We find that the pumps require about 80 cu. ft. of air per minute to handle 180 g.p.m., while the clay diggers repair about 33 cu. ft., and the tampers, 28 cu. ft. per minute.

Maintenance of Automotive Equipment

Automobiles and trucks are also inspected at monthly intervals. This has proven to be a very good investment. Since inspections were started, there has not only been a decided improvement in the general condition of the units, but breakdowns on the road have been much less frequent.

All cars are washed and greased bi-weekly by the night emergency men, and after every second washing are kept in the shop the next day to allow a mechanic to go over the unit, tighten the chassis, adjust brakes, carburetors and other equipment. Defects which cannot be repaired in the four hours allotted to the mechanic to work on the car are reported to the foreman, who makes arrangements for the work to be done at a later date. In this way the yard foreman has a definite knowledge of the condition of the cars and there is no excuse for breakdowns.

The cars are all equipped with oil filters and oil is changed only twice a year. The filter cartridges are changed whenever they become dirty, which varies between 4,000 and 6,000 miles, depending on the condition of the motor. At one time we had about fifteen drums of crankcase drainings. To use up this old oil a Skinner Oil Filter was set up in our filter plant, where our



Emergency Truck with Motor-Operated Gate Mechanism (right) and Air-Operated Gate Wrench (left).

[*A paper presented before the New England Water Works Association, and reproduced by permission of the Association.—Editor].

own electricity is available. This filter takes the impurities out of the spent oil and its output is about 2 gallons per day. The filtrate, with an SAE number of about 30, has been used successfully in the older trucks, now for about two years.

The average cost per mile for operating 23 half-ton pickup trucks was 3.65c per mile last year, and for operating eight 4-ton trucks, 6.3c per mile. The costs include office overheads, insurance and tires, but do not include depreciation.

All pumps, large main-tapping machines and similar equipment are checked after being used. By this procedure, all equipment is kept in a condition to operate at all times.

Meter Shop Practices

Much the same procedure is followed in the care of meters. We plan to bring into the shop each year one-fifth of all our meters. This program, which was started in 1932, was completed for the first time in 1936 when we tested over 9,000 meters.

Although we now have 2,160 more meters than in 1934, last year 467 fewer meters were removed for all causes, other than routine tests, than in 1934. We believe that this improvement is largely due to eliminating the weak lines before they break down.

Used Meters Must Meet New Meter Accuracy

Upon arrival at the shop all meters are tested at a rate of ¼ their rated capacity, after which each meter is torn down, washed, and reassembled with necessary new parts. Every repaired meter is then tested and must meet the requirements of the NEWWA specifications for accuracy of *new* meters.

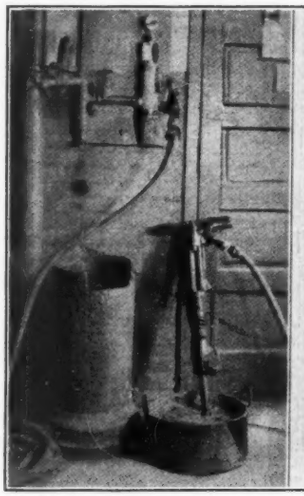
All worn gear trains are repaired in the shop and certain of the chambers are remachined and pistons refitted to the chambers. Other chambers are repaired at the various meter factories, if we cannot quickly fit new discs to them ourselves. When repaired meters were first required to meet the NEWWA accuracy requirements for new meters, it was necessary to revise our testing procedure. Previously, on the minimum test flow, which in the case of a ⅝-inch meter is 0.25 g.p.m., we ran water at this rate through the meter for three minutes. For a 100% registration, the meters should read 0.1 cu. ft. Since it was almost impossible to diffferentiate between 0.08 and 0.09 of a cu. ft. and since 0.09 was required for the meter to pass, it was necessary to run a full foot of water into a one-foot test tank. This takes 30 minutes, and it seemed a waste of time and labor to have a man spend a half hour watching water run into a can.

Automatic Meter Test Run

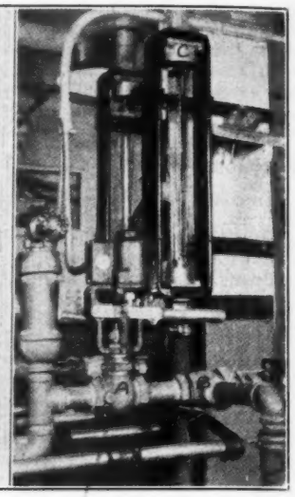
The present electrical apparatus was rigged up to meet this condition. The flow is now started by opening a solenoid valve. When the test tank is filled a float in the tank closes an electrical circuit which trips the valve and shuts off the water. The volume in the tank is controlled by this means to within 1/10th of 1 per cent. By this means it is possible for one man to test two strings of 8 meters, each simultaneously, and on each flow enough water is run so that the test hand of the meter always makes at least one complete revolution.

In the picture of the meter test equipment, the water goes through the meters which are at left of the picture, thence through the solenoid valve "A" and the flow control valve "B" to the Ford Testerate Indicator "C" (shown above valve "B"), and then to one of two tanks. The large one is of 10 cu. ft. capacity and the smaller one holds 1 cu. ft. Each has a conical bottom and a reduced section at the top for greater accuracy. One of the two pipes coming out of the top of the tanks is used for filling, and the other contains the float.

This work is under the direction of Caleb Mills Saville, manager and chief engineer of the Water Bureau of the Hartford (Conn.) Metropolitan District, and of Harold W. Griswold, deputy manager and deputy chief engineer.



Paving Breaker Under Efficiency Test (air meter on wall above).



Equipment for Automatic Meter Test Run ("A"—Solenoid Valve; "B"—Flow Control Valve; "C"—Ford Testerate Indicator).

EVALUATION OF PUMP BIDS BY A SIMPLE METHOD AND DETERMINATION OF POWER COSTS

The estimated cost of electrical energy for pumping liquids over any assumed period of time, which is to be added to the bid price for pumping equipment for determination of its evaluated cost, may be obtained through the use of the formula

$$C = \frac{3.14\ Qhc}{E}$$

Where C = Estimated power cost in dollars over the assumed evaluation period.
Q = Estimated number of *millions* of gallons to be pumped during the same period.
h = Head in feet, on which guaranteed efficiency is based.
c = Cost, in dollars, per KWH of electrical energy.
E = Guaranteed overall pump and motor (input-output) efficiency at head "h," expressed as decimal fraction and not as a percentage.

The constant "3.14" is suitable for slide rule calculations and is sufficiently accurate for most cases, as the assumptions made are too broad for accurate estimates. Should it be necessary to determine the cost to the dollar (in case of very close bids and the selection must be made on a price basis), the figure 3.13975 should be used.

Example: Assume
Q = 2,000 million gallons
h = 100 feet
c = $0.01 per KWH
E = 0.7 (70 per cent)

$$C = \frac{3.14 \times 2{,}000 \times 100 \times 0.01}{0.7}$$

$$= \$8{,}970.$$

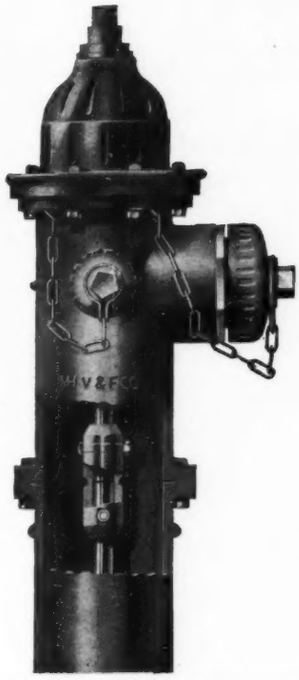
This simplified formula for evaluating pump bids was developed by C. I. Dodd of Black & Veatch, Engrs., Kansas City, Mo.

M & H VALVE AND FITTINGS COMPANY

ANNISTON, ALABAMA

VALVES, HYDRANTS AND WATER WORKS ACCESSORIES

Protection of public water systems and fire protection for municipalities under war conditions involves a greatly increased number of control valves and hydrants on the water mains. M & H products with their record of high quality, rugged strength and dependability can safely be recommended.



M & H FIRE HYDRANTS

Conform to latest A.W.W.A. specifications. Simple, rugged design minimizes maintenance costs. Features are:

1. Dry Top—Operating threads protected from action of water. No rust, corrosion or freezing.
2. Easy Lubrication of operating nut, threads and packing through lubricating screw in top of operating nut.
3. Revolving Head, outlets faced in any direction.
4. Addition of Steamer Nozzle, without digging up hydrant or requiring complete new barrel.
5. Lengthening of Hydrant without digging up or requiring complete new barrel.
6. Double Lead Gaskets on Bronze valve seat.
7. Removal of Bronze Seat, or any working part, without digging up Hydrant.
8. Double Drain Valves, absolutely positive, insuring quick and complete draining of Hydrant.
9. Lugs on Bell of Hydrant Shoe for strapping to the water main, if desired.
10. Compression Type. Water pressure keeps valve tight.

SPECIAL TRAFFIC MODEL FIRE HYDRANT

Equipped with cast iron bolts and breakable coupling on the stem. Breakage due to traffic collision is limited to these cast iron parts which are easily and quickly replaced without shutting off the pressure.

M & H A.W.W.A. GATE VALVES

Iron body, bronze mounted gate valves are furnished in the double disc parallel seat or solid wedge types with non-rising stem, outside screw and yoke, or with sliding stem and lever. Supplied to fit any standardized pipe connections. By-pass valves can be furnished, unless otherwise specified, in sizes according to A.W.W.A. specifications.

SPECIAL TYPES

Hydraulically Operated: for remote control of operation and for quicker, easier opening or closing. Can be supplied in any of the standard sizes of M & H A.W.W.A. gate valves, either high or low pressure.

M & H Square Bottom Gate Valves: specially designed for operation in any position. Particularly recommended for use in intake towers or at the foot of dams; for pressure regulation by throttling the flow of water in centrifugal pump discharge lines; for regulation of flow in feed line to a filter bed; and for flow regulation from a reservoir where there is unbalanced pressure against the gates.

PRESSURE CLASSIFICATION—2″ TO 30″ SIZES

Class	Working Pressure	Hydrostatic Test
AA	0 - 25 lb.	50 lb.
A	26 - 50 lb.	100 lb.
B	51 - 100 lb.	200 lb.
C	101 - 200 lb.	350 lb.

CHECK VALVES

For installation in horizontal or vertical position. Can be supplied with by-passes. May be furnished with outside lever and weight. Sizes from 2″ to 12″ for working pressures up to 200 lbs.

OTHER PRODUCTS

Tapping Valves
Mud Valves
Shear Gates
Flap Valves
Wall Castings
Floor Stands
Flanged Fittings
Flange and Flare Fittings
B & S Fittings
Cutting-In Tees
Valve Boxes
Special Castings

WATER REQUIREMENTS*

Volume Demand and Rates of Flow for Various Uses and Fixtures

Twenty gallons per capita daily is generally conceded to be the absolute minimum quantity of water needed to carry out, properly, the various functions of life of those served a supply of water piped into the property.

The basis for such a per user estimate is the following:

Drinking	1 gal.
Laundry	6 "
Bathing	5 "
Toilet (2 flushes)	5 "

(Possibly the item "Drinking" includes all water used in the kitchen. However, nothing is shown for scrubbing and other miscellaneous uses. So it is apparent that the average per user requirement should be at least 25 gallons and the *reasonable* minimum probably more nearly 30 gallons. In fact, surveys have revealed such to be the case.)

In a recent review of water consumption data the following procedure in estimating appears.*

"For purposes of estimating the probable use of water in a given building the engineer considers those quantities which are used for specific domestic operations and which do not vary appreciably with size of family, as well as the basic consumption rate of 20 gallons per capita per day. The total amount of water used in sprinkling a lawn does not vary with the number of persons living in a given house, nor does the quantity used for washing the family car. On the other hand, the use of water for personal bathing is directly related to the number of persons in the household.

"The figures which are presented here are subject to some variation but they may well serve as an index of the amounts which may reasonably be considered to be used in carrying out various domestic operations. Studies here and abroad have indicated that about one-half to two-thirds of the water used in ordinary household consumption is heated (bathing, laundering, dishwashing, etc.)."

Operation	*Quantity-of-Water*
Tub bath	25 gallons/bath
Shower bath	5 gallons/min.
Additional toilet flush/person	6 gallons/diem
Sprinkling lawn (⅝-inch hose)	7 gallons/min.
Washing automobile	150 gallons
Basic quantity/person	20 gallons/diem

"Two examples will illustrate the use of these data.

Example 1.—A family of five persons is to build a single house on a lot 50 by 100 ft. in a fairly good neighborhood. They plan to have a bathtub and do home laundering, but they have no automobile. How much water per capita (in round numbers) should be estimated as the daily consumption for this family

Basic figure $= 5 \times 20 = 100$ g.p.d.
Lawn watering $= 20$ min./diem for 3 mos. $=$ 5 min./diem $= 35$ g.p.d.
Bathing—2 baths/week/person $= 5 \times 50/7 =$ 35 g.p.d.
Total $= 170$ g.p.d.
Per capita consumption $= 34$ g.p.d.

Example 2.—A family of three is to build a large house on a plot 125 by 250 ft. in an exclusive section of town. Laundering is to be done at home and the two cars probably will be washed twice a month at home. There is a shower for the head of the house, and two baths for the two women. What water consumption per capita could be estimated here?

Basic figure $= 3 \times 20 =$	60 g.p.d.
Additional toilet flushes, $3 \times 6 =$	18 g.p.d.
Lawn watering 1 hour/day for 4 mos. $= 20$ mins./day for the year $=$	140 g.p.d.
Bathing—2 baths/day $=$	50 g.p.d.
Showers—10 min./diem $=$	50 g.p.d.
Washing cars—600 gal./mo. $=$	20 g.p.d.
Total	326 g.p.d.
Per capita consumption	109 g.p.d.

Similar methods of approach may be used in solving problems involving large apartments and housing projects."—Jour. A.W.W.A.

In an analysis of available survey statistics from representative cities, essentially, the following conclusions appear in the same article.*

(1) The minimum domestic water requirements for an urban community or household should be assumed at not less than 30 gals./capita/day.

(2) For design of systems, service lines and interior piping it is safer practice in general to use a figure of 40 gals./capita/day.

(3) The increase in consumption can be estimated at a rate of 1% per year, until a maximum of 50 gals./capita/day is reached.

Water Requirements in Various Types of Housing

The following estimates of expected consumption in various types of housing are based on data presented in the same review.

Type of Housing	*Gal./Capita/Day*
Single Family Houses	
Minimum	35
Reasonable	55
Maximum	100+
2, 3 and 4 Family Houses	
Minimum	35
Average	40
Maximum	55
Apartment Houses	
Average	75
Maximum	100+
Housing Projects	
Minimum	35
Reasonable	45**
Maximum	90

RATES OF DRAFT PER FIXTURE OR USE

Individual Needs	Gallons per Day
For all household purposes, including kitchen, laundry, bath, etc.	30
Each cow	10
Each horse	10
Each hog	5
Each sheep	5
Continuous flowing drinking fountains	75

Lawn Fixtures	Gallons per Hour
½-inch hose with nozzle	200
¾-inch hose with nozzle	300
Lawn sprinkler	120
Park or golf course sprinkler covering a 106-ft. diameter area, with ¼-inch main nozzle operating at 50 lbs. nozzle pressure	990

Domestic Fixtures	Gallons
Filling the ordinary lavatory	1½
Filling the average bath tub	30
Flushing water cabinet closet	6
Shower bath	30

(*From, Peerless Pump Bulletin*)

*Based on data and computations in a review of water requirements in "Domestic Water Consumption" Jour. A.W.W.A., December, 1939—by M. A. Pond, and published information from various other sources.

**In measuring the proportion of total consumption that was used as heated water the average was 66%, or 28 gallons in the average total of 42 gallons used per head.

RATES OF FLOW FROM FIXTURES

Fixture	Gallons per Minute† Fair	Good	Excellent
Bath Tubs	5	18	10
Showers (5" to 8" heads)	3	6	8
Lavatory Basins	3	5	8
Laundry Tubs	4	8	10
Sinks (Kitchen & Pantry)	4	8	10
Hose (Sprinkling & Washing)	5	8	10
Toilet Flush (Tank)	2	3	5
Toilet Flush (Flushometer)	20	30	40

†Copper and Brass Research Association figures, supported by other data.

Expected Consumption Rates and Requisite Pipe Sizes in Apartment Buildings

The following tables taken from a bulletin of the Bridgeport Brass Co. indicate expected reasonable rates of draft by apartments of various sizes and number of baths. Also is listed the minimum sizes of service lines and recommended sizes of riser pipes, based on a pressure loss of 10 lbs./100 ft. of run, and terminal fixtures pressure of 15 lbs./sq./in. during water use in all apartments on the same riser, from top floor to ground.

TABLE 1.

RATES OF USE AND WATER SUPPLY RISERS FOR APARTMENT HOUSES

(Based Upon 1-2 & 3 Baths per Ap't.)

One (1) Bath Apartment		Two (2) Bath Apartment		Three (3) Bath Apartment	
1 bath	15 gals.	2 baths	24 gals.	3 baths	30 gals.
1 W. C.	8 gals.	2 W. C.	14 gals.	3 W. C.	18 gals.
1 sink	4 gals.	1 sink	4 gals.	1 sink	4 gals.
1 lav.	4 gals.	2 lavs.	6 gals.	3 lavs.	9 gals.
	31 gals.		48 gals.		61 gals.
50% demand, 15 gals. per min.		40%, 20 gals. per min.		40%, 24 gals. per min.	

		RISER		RISER		RISER
Top Floor	15 gals.	1¼"	20 gals.	1¼"	24 gals.	1¼"
Next	28 gals.	1¼"	38 gals.	1½"	43 gals.	2"
Next	38 gals.	1½"	54 gals.	2"	64 gals.	2"
Next	51 gals.	2"	68 gals.	2"	82 gals.	2"
Next	60 gals.	2"	80 gals.	2"	96 gals.	2½"
Next	67 gals.	2"	90 gals.	2"	108 gals.	2½"
Next	71 gals.	2"	98 gals.	2½"	117 gals.	2½"
Next	78 gals.	2"	104 gals.	2½"	124 gals.	2½"
Next	81 gals.	2"	108 gals.	2½"	134 gals.	2½"
Next	83 gals.	2"	110 gals.	2½"	143 gals.	2½"
Next	84 gals.	2"	110 gals.	2½"	143 gals.	2½"
Next	85 gals.	2"	110 gals.	2½"	143 gals.	2½"

TABLE 2.

APARTMENT HOUSE SUPPLY SIZES OF SERVICE LINES FROM MAIN

(Based on Pressure Loss of 10 lbs./100 ft. Run)

For 4 and 5 Stories

No. of Baths	APARTMENTS PER FLOOR Four Gals.	Four Main	Six Gals.	Six Main	Eight Gals.	Eight Main	Ten Gals.	Ten Main
1 bath	120	2½"	160	3"	200	3"	240	3"
2 baths	160	3"	200	3"	240	3"	280	3"
3 baths	200	3"	240	3"	280	3"	320	3½"

For 6, 7 and 8 Stories

No. of Baths	APARTMENTS PER FLOOR Four Gals.	Four Main	Six Gals.	Six Main	Eight Gals.	Eight Main	Ten Gals.	Ten Main
1 bath	150	2½"	190	3"	230	3"	270	3"
2 baths	190	3"	230	3"	270	3"	310	3½"
3 bath	230	3"	270	3"	310	3½"	350	3½"

For 9, 10, 11 and 12 Stories

No. of Baths	APARTMENTS PER FLOOR Four Gals.	Four Main	Six Gals.	Six Main	Eight Gals.	Eight Main	Ten Gals.	Ten Main
1 bath	200	3"	250	3"	300	3½"	350	3½"
2 baths	250	3"	300	3½"	350	3½"	400	3½"
3 baths	300	3½"	350	3½"	400	3½"	450	4"

DELIVERY THROUGH BRASS AND COPPER PIPES OF VARIOUS SIZES FOR VARIOUS PRESSURE DROPS

(Each line being 100 ft. long)

Pressure Drop (Lbs.)	Gallons per Min. Delivery Through ⅜"	½"	¾"	1"	1½"	2"	2½"
5	2	3	7	13	40	80	150
10	3	5	10	20	60	130	225
20	4	7	15	30	90	200	300
30	5	9	20	40	120	250	375

Blotting Out Waste

Safe Water
delivered night and day
Costs Less
than anything else you buy
• • *but* • •
Don't Ignore Leaks!

Satisfied customers are worth more to us than revenue secured from water *uselessly* passing through meters.

INDIANAPOLIS WATER CO.

What Leaks May Cost

Size of Leak	Gallons per 24 Hours	Gallons per Month	Cost per Month
½"	47,600	1,451,800	$156.21
¼"	12,300	375,150	60.05
⅛"	3,200	97,600	19.65
1/16"	860	26,230	6.35
1/32"	215	6,550	1.97

(Above estimates are based on Indianapolis pressures without allowance for friction loss)

The above is a reproduction of the top side of a little blotter sent out to customers, reminding them of the high cost of allowing fixture leaks to persist. If as good at blotting waste as ink, the scheme is praiseworthy.

Incidentally, the Indianapolis Water Company gets in a good public-relations message about satisfied customers being worth more to them than the added revenue from the uselessly metered wastage.

SAND REMOVAL FROM WELL WATER

Some Notes on the Use of Brassert Automatic Self-Cleaning Strainers at Houston, Texas

By G. L. FUGATE, Chief Engineer
Water Department, Houston, Texas

THE acquifers of the ground source of water supply in the West Gulf Coastal Plain, in which Houston is located, are composed of unconsolidated sands. At Houston some of these sands are of such size that 95 per cent is retained on a 150 mesh screen and the remaining 5 per cent is retained on a 200 mesh screen. The best constructed wells will produce some sand, and more when operated intermittently.

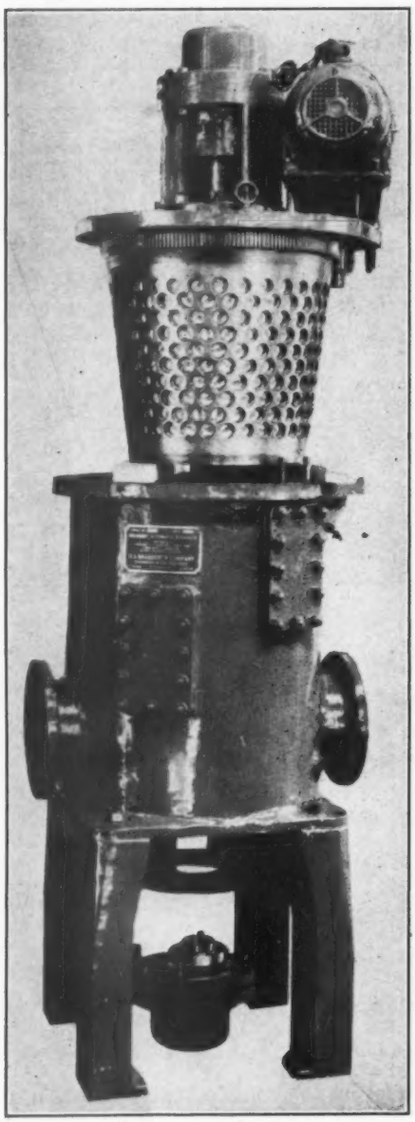
Many of these fines in the 5 per cent retained on the 200 mesh are conical shaped. They settle slowly and the velocity through the relatively small suction storage tanks is often too high to permit their removal by sedimentation. As a result, they are transmitted into the distribution system. This in turn causes customers to complain and creates troublesome and expensive meter maintenance and possible loss of revenue because of clogged or damaged meters.

Such conditions brought about studies to determine how the fines might be removed by means of mechanical equipment. These studies led finally to installing two Automatic Mechanical Strainers, manufactured by H. A. Brassert & Co., of Chicago. One installation was made at the Scott Street Plant and one at the South End Plant.

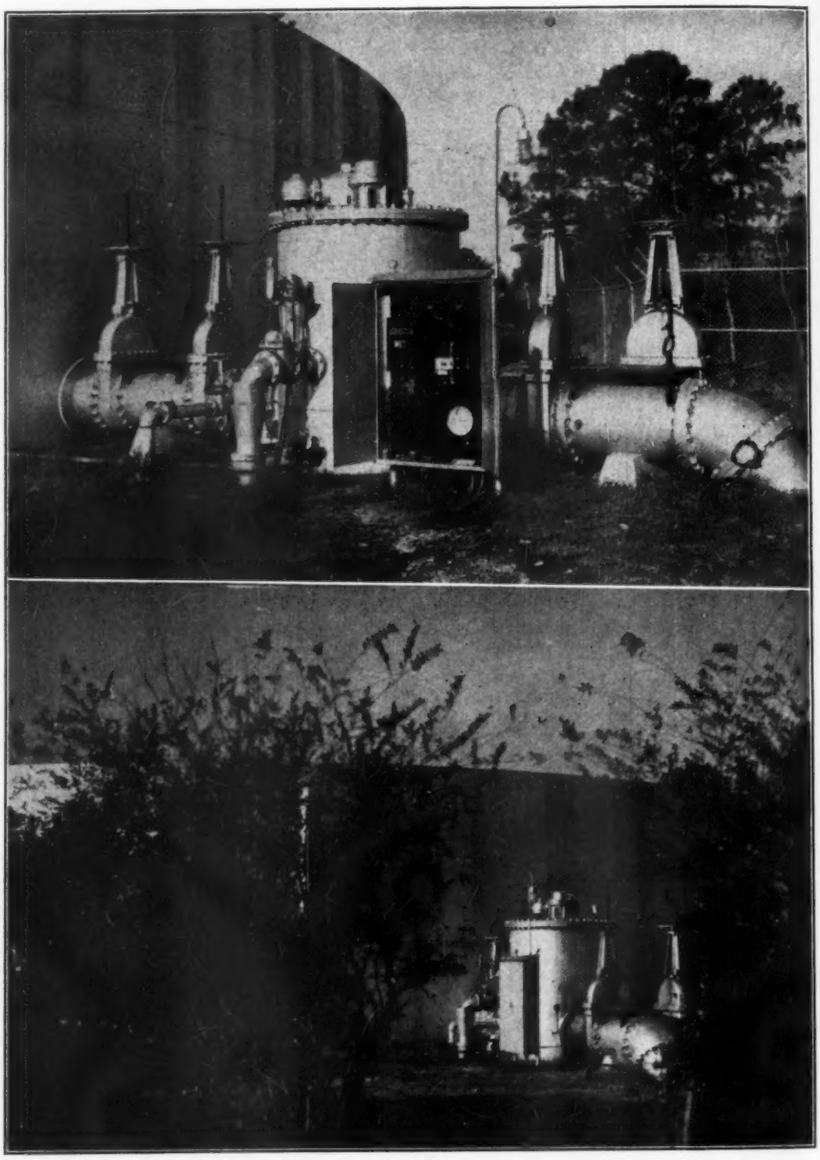
It is believed that the installation of these strainers here at Houston in the Fall of 1939 represents the first application of these industrial water supply strainers for the interception and removal of fine sand from a public water supply. We understand that more recently an installation of the same sort has been made in El Paso, Texas. There are possibly others also by this time. With Houston, however, the scheme appeared to be sound but the installation was made on an experimental basis.

The Brassert Strainers

Construction details of these automatic self-cleaning mechanical strainers are shown in Fig. 1, a drawing supplied by the manufacturer.



A Brassert Strainer
Showing the screen studded revolving cone. Houston strainers have 2,528 of these screens.



Two Views of the Automatic Sand Strainers at Houston, Texa.

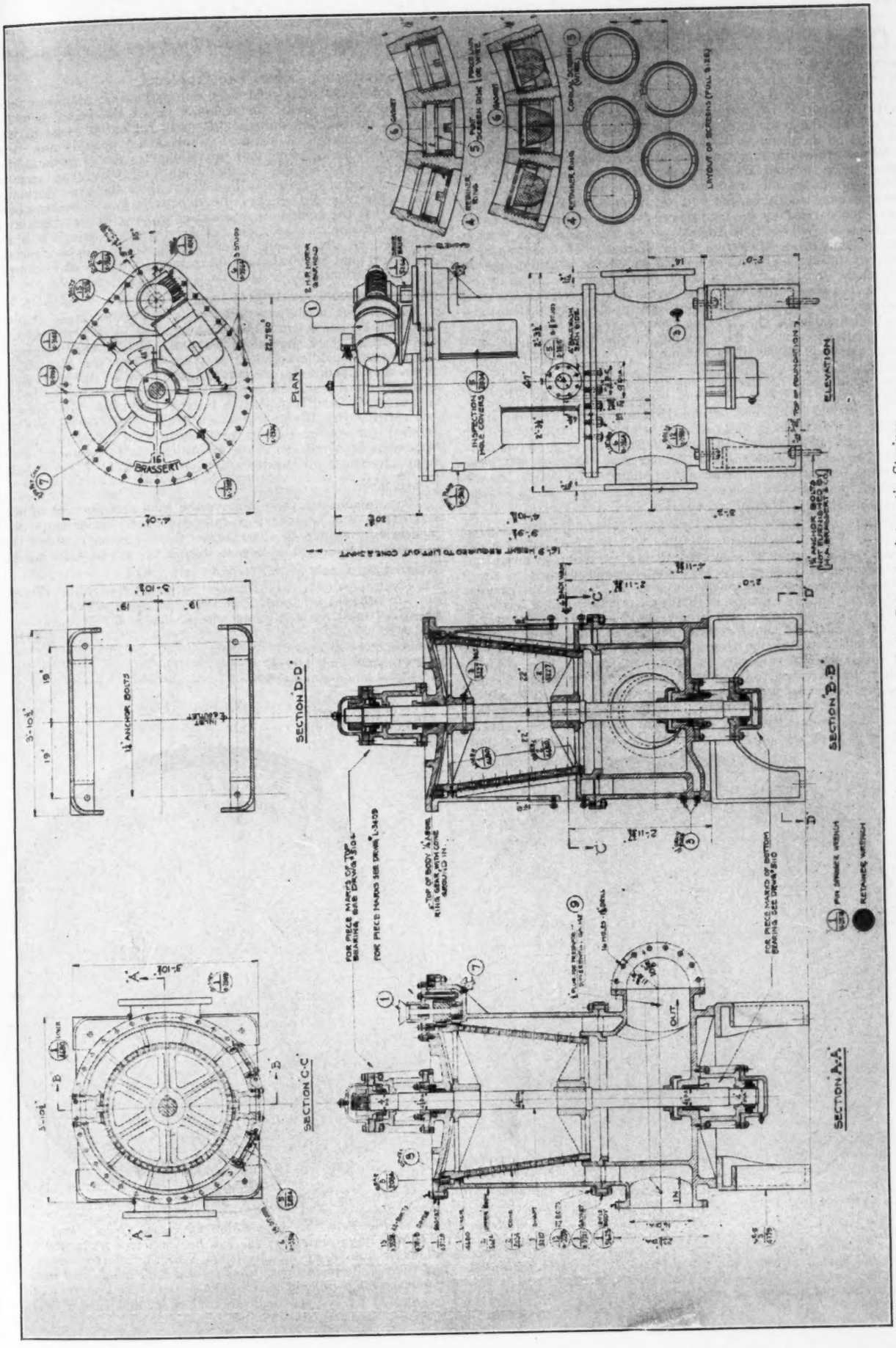


Fig. 1—Manufacturer's Drawing of the Brassert Automatic Strainer

Briefly described, the Brassert strainer consists essentially of a rotating cone-shaped drum, fixed to a vertical shaft, centered within a cast iron housing. The entire vertical surface of this drum is drilled with rows of holes into which are inserted the screening media. A washout orifice, in the form of an internal vertical slot cast integrally with the housing, is machined and lapped into the contour of the drum to engage one vertical row of holes on the drum as it rotates.

Water enters through an inlet at the bottom of the housing, then, rising around the revolving drum, passes through the screening media and into the drum. In the process, sand or other matter to be strained is accumulated on the screening discs and carried by the continuous rotation of the drum to the washout slot, where it is flushed out by a reverse flow of clean water from inside the drum. The discharge of clean water is effected through an outlet at the bottom of the housing, opposite the inlet.

The drawing (Fig. 1) used with this description is of a smaller sized unit than the 24-inch units installed in Houston—the substitution of the drawing being a result of the fact that the small lettering on the drawing of the Houston units, and greater amount of detail, is not subject to as satisfactory reproduction in magazine page size. Even so, some of the unimportant details may not be readable without use of a magnifying glass.

The 24-inch units instal'ed in Houston weigh approximately 19,000 pounds each, have an overall height of a little better than 108 inches, and measure 76 inches from inlet to outlet flanges. The strainer drum contains 2,528 screening discs of 200 mesh stainless steel screen. The drum is rotated by a 5 hp. 220-volt motor.

Operating Experiences

When these strainers were put into operation they clogged rapidly. Under the microscope the conical shaped sands, mentioned before, could be seen wedged in the screen openings and the automatic low pressure back-wash was insufficient to effectively dislodge them. A connection was made to the distribution side of the high lift pumps so that high pressure and a relatively large volume of back-wash water could also be used as required at intervals and for short periods of time. This method proved effective and the frequency of high pressure back-washing varies with the quantity of sand in the water. The strainer units must be valved off from service during the high pressure washing, and this procedure, without power operated valves, proved more or less laborious. The State Hea'th Authorities ruled that the high pressure back-wash line was a cross connection between treated and untreated water and its use for a time was abandoned and the strainers not operated. This objection has now been eliminated.

Pre-Chlorination Solves Two Problems

As the result of a gelatinous, non-pathogenic organism found growing in the wells, the chlorination of the water before it entered the suction storage tanks was begun, to assist in taste and odor control. A residual of about 1.4 ppm. is now being maintained in the tanks and this eliminates the cross-connection objection. The strainer at the South End Plant has been put back into service and it is found that since the pre-chlorination was begun, the clogging of the screens is less. The reason for this is that the gelatinous material enveloping the sand grains is, by chlorination, broken away, leaving the grain clean. It is also noted at the other plants, where sedimentation only is depended upon for sand removal, that the removal there is also improvd by pre-chlorination.

Washing Economy Improved

To conserve wash water, the drain from the screen chamber has been equipped with an automatic valve. When the pressure has increased to a predetermined value, due to the clogging of the screen, the differential of pressure between the feed and the drain sides operates an electric motor control so that the valve is opened and the screens are back-washed automatically by low pressure. A time relay on the control holds the valve open for one entire revolution of the screen drum. This scheme was substituted for the continuous back-wash. The quantity of wash water has been reduced about 75 per cent in this manner. Operating charts on the strainers are reproduced as Figs. 2 and 3.

Conclusion

The strainers definitely remove the sand and the cost of their installation and operation is fully justified. Like any other pioneering installation, there were "bugs" to be removed, and experience has taught us how to iron these out one after another.

Operating Costs

Operating Cost of Brassert Strainer Based on 1941 Pumpage, South End Plant, Houston, Texas.

Increased head on well pump with power at 6 mills per KWH	$225.00
5 horsepower to operate strainers	196.00
Amortization and interest at 6%	360.00
No extra labor employed.	
Per annum	$781.00
Per million gallons	0.48

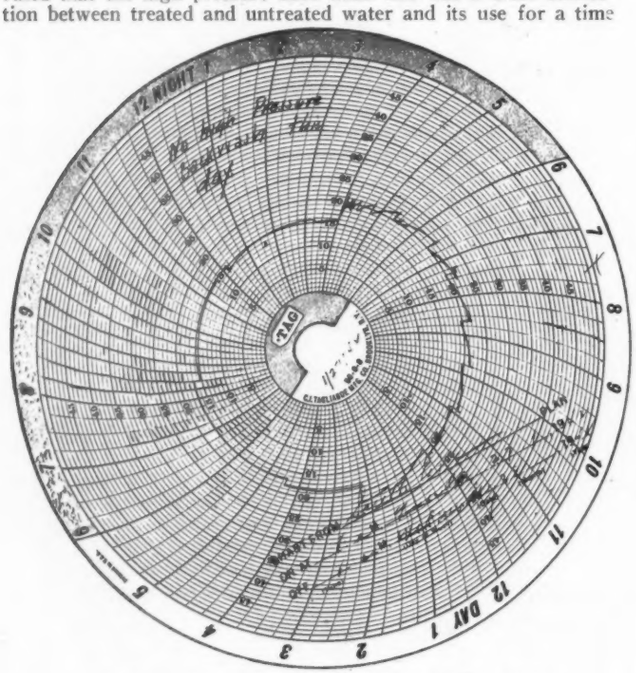


Fig. 2—Operating Chart for South End Plant
(Note that no high-pressure washes were required during this operating period. Where the pen drops back indicates the automatic low pressure washes, their frequency depending upon pumping rates and quantity of sand being delivered by the wells.)

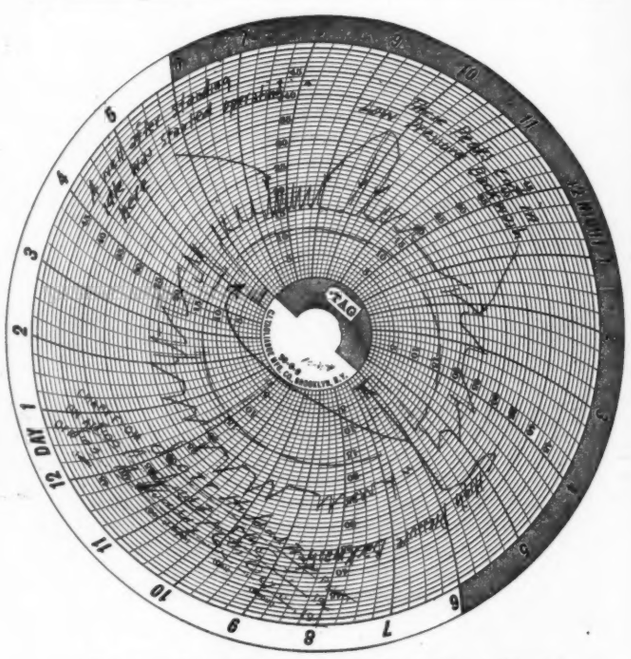


Fig. 3 —Operating Chart for Scott Street Plant
(The saw tooth pattern of the pen line indicates frequency of the automatic low pressure back-wash. Note the effect between 7:30 and 9:00 A.M. from the cutting in of a well which had been out of service for a time. The two high-pressure back-washes are indicated by the pen drop at 5:30 A.M. and 5:10 P.M.)

RATING AND SAMPLING WELLS BY AN IMPROVED METHOD

By PAUL F. HOWARD, M.S.*

Consulting Engr., Boston, Mass.

It is oft-times desired and of importance to ascertain the quantity and quality of water yielded by an individual driven well connected to other wells of a water system. Experience has shown that analyses of samples of water taken from individual wells by means of a hand pitcher-pump give false and meaningless results, especially in relation to the iron content. Likewise the yield of an individual well by means of separate pumping furnishes but little if any information as to the yield of the individual well when ganged together into a common system.

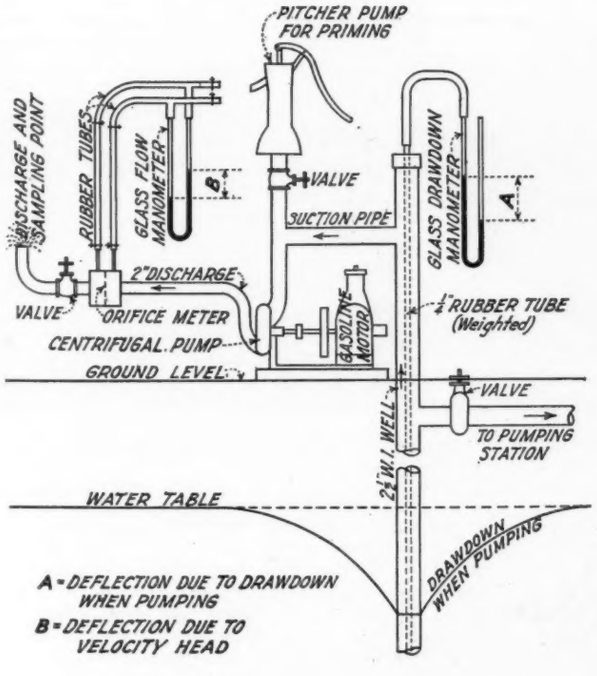
The writer's firm was engaged to investigate a water supply from about 90 driven wells. During the course of the work it became desirable to determine the yield of each individual well and the iron content of the water from each individual well under normal operating conditions. This was done by a device which we have called a Well Rater and Sampler. The device (see cut) was connected to the top of the well by a 2½ inch wrought iron pipe about 2½ feet long. At this point a 1¼ inch centrifugal pump was connected by the proper fittings and discharged through a 2 inch pipe. On the suction pipe a hand pump was attached to prime the pump. A 2 inch orifice flow meter was inserted in the discharge line and by means of a manometer the rate of flow was determined. The amount of the draw-down of the well, when connected to the well field, was determined by means of a mercury U tube connected to a small tube attached to the well cap, the tube extending into the well to a depth sufficiently great so that the end was at all times below the level of the water-table outside of the well.

Before the Well Rater and Sampler was connected to the well the permanently installed valve on the suction line was closed. After the device was connected this valve was opened and the well was observed under actual working conditions—i.e., while it was being pumped along with the other wells by the large pump in the pumping station. The drawdown was revealed by the reading of the manometer connected to the tube in the well and recorded. Thereafter, the permanently installed valve was closed and the centrifugal pump started, the rate of pumping being controlled by a valve on the discharge line. As the discharge increased the drawdown increased, thus producing a deflection on the manometer. When the manometer reading was the same as that already observed under the actual working conditions, as just described, the output of the well was assumed to be the same. The quantity being pumped was then determined by observing the deflection of the flow manometer on the pump discharge line. The results represented the actual amount of water that the well was contributing from the field as a whole when under *actual* pumping conditions. Samples of water for analyses, then taken at the point of discharge, were considered truly representative samples.

By careful operation of the valve at the discharge end of the pipe the yield of the well was brought gradually up to the original yield at the beginning of pumping. Thereby higher velocities than usual or ordinary in the pipe well were provided. Any excess velocities would, of course, free scale, rust and other matter and give false samples. The flow manometer in this particular instance was connected to the 2 inch orifice flow meter. [The liquid used to determine the differential pressure can be of any specific gravity desired depending upon the rate of flow to be measured. The most common is mercury for high flows and carbon tetrachloride, Specific Gravity 1.60, for low flows.]

One side of the mercury U tube was connected to the tube in the well and filled with water from the surface of the mercury to the water level in the well, care being taken to remove all air. The other side of the U tube was left open to the atmosphere.

*Whitman and Howard, Engs., Boston, Mass.



WELL RATER AND SAMPLER

The Hook-Up of the Well Rater and Sampler

A Specific Case

The following specific example will serve as an illustration. After the Well Rater and Sampler had been properly set up and connected to a well the mercury U tube was connected to the tube in the well. There was an initial deflection of mercury of 3 inches which represented a water column of 40½ inches, the distance from the water table to the mercury surface of the U tube. After an equilibrium had been reached the well was connected to the field and the mercury in the U tube deflected an additional amount corresponding in general to the distance the water table dropped outside of the well and specifically to the drop in pressure in the well. In this case the total deflection was 4¼ inches or a difference in deflection of 1¼ inches which equal 17 inches of water as the drawn down within the well.

The well was then shut off from the other wells and the small test pump started. The discharge valve on the pump was then opened slowly, increasing the yield of the well until the drawdown deflection of mercury showed 4¼ inches. After this point was reached the flow manometer was observed to have a deflection of 1⅝ inches of mercury which on this meter represented a flow of 20.1 gallons per minute.

The yield of the various wells in relation to the drawdown was plotted on arithmetic paper and the yield of each well was found to be directly proportional to its drawdown. The yield of the various wells varied from 1 to 25 gallons per minute and the drawdown varied from 5½ to 26 inches.

This device has been made use of in installing new driven well fields. By its use we have been able to predict reasonably well the draw down or vacuum to be expected in a system of driven wells and to eliminate uneconomic wells, which have a low yield in relation to the drawdown. Also with open end wells it has been possible to determine at what yield a well will throw sand sufficiently to result in filling up by sand. The equipment will probably be found to have other uses also.

Acknowledgment—The above paper was presented before the New England Water Works Association, at Providence, R. I., Sept. 19, 1935, and appeared in WATERWORKS & SEWAGE for December, 1935.

PROTECTING A RESERVOIR AGAINST ICE

A Simple Scheme That Has Proved Effective at Augusta, Me.

By H. J. COOK, Engineer and Superintendent
Auburn Water and Sewer Districts, Auburn, Maine

MORE than thirty years ago, a concrete reservoir was constructed by the Auburn Water Commission which then was operating the public water supply system of the City of Auburn, Maine. The interior walls of this structure were nearly vertical.

During its construction very little attention was paid to the bonding of the successive day's runs. As some of this concrete was poured during freezing weather without proper precautions, the joints between the different days' work were weak.

When spring came, longitudinal cracks appeared at these locations allowing extensive leakage. Apparently ice action was the cause of these failures.

Various methods were tried to remedy this condition, but only temporary improvement resulted. When spring came, the same leaks reappeared.

As the seasons passed, these leaks grew larger and the repairs more costly. Finally the interest on the money needed to make permanent repairs became less than the cost of pumping the water leaking through the walls.

In 1940, a thick coating of Gunite was applied to the entire inside walls of the reservoir.

Of course, Maine has real winters, and the real test of this Guneit lining was the manner in which it withstood the action of the ice.

Protection Against Ice

In order to decrease the effect of the expansion of the ice, and of the rising and falling of the ice surface, a string boom of logs was placed in the reservoir extending around the whole perimeter and kept about three feet from the walls.

This boom was made of pine logs from 16″ to 24″ in diameter. These were cut on the Lake Auburn watershed, the source of supply for the municipality, and on property belonging to the Auburn Water District which now operates the public water supply system.

These logs were peeled and placed end to end in the reservoir; being joined by a splice of two-inch planks spiked firmly to each. Every hundred feet or so a two-inch plank, about three feet long, was fastened at right angles to the boom to keep it away from the walls (see photos).

How the Boom Worked

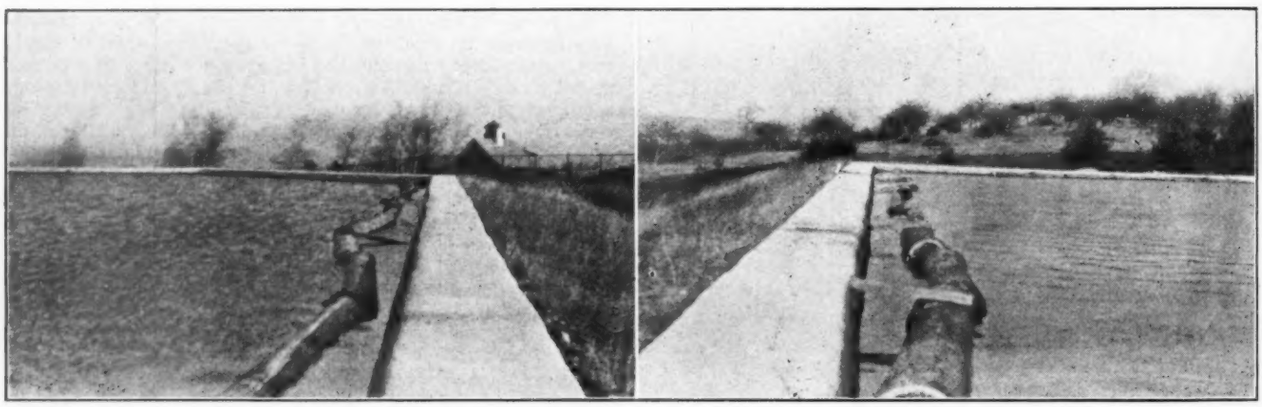
On visits to the reservoir during the winter, ice cracks along the line of logs were visible. It looked as though the boom was acting like a hinge, and as the ice rose and fell it cracked and heaved along this axis.

There may be another action by which protection is given the walls by this device. As the winter progressed, several of the three-foot pieces of the bumper plank were torn off by the ice and the logs were pushed against the walls. As the ice rose, fell, and expanded, these logs appeared to move up and down the sides of the reservoir as rollers.

As spring approached, the ice between the boom and the walls melted days before that in the remaining section of the reservoir. Many of the planks holding the logs together had pulled off, breaking the boom into small parts, but the walls were intact.

The logs were rolled out and piled during the summer to prevent them from becoming water soaked. This fall they were replaced in the reservoir. However, chains were used to connect them this time. It is hoped that this boom will hold together better. Also it was much easier to construct with the use of chains.

Whether the successful result of last winter was due to the use of a boom or to a good job of Guniting, or to a combination of both, the fact remains that for one year at least the walls have withstood the rigors of a Maine winter.



Log Booms for Ice Damage Prevention in Augusta, Me., Reservoir. (As they looked after the first year's duty.)

METERING: PRACTICAL METHODS OF PROCEDURE*

By E. H. RUEHL†
Richmond, Va.

"TO METER or not to meter?" That is the question. Those who have gone through the problem of making initial installation of water meters know what significance these few words can have and what discussions can be caused thereby.

However, metered water service is being acknowledged more and more as being the best all-round method of distributing the indispensable commodity, water. This is especially true since the unprecedented drought of 1930, and I am sure that if more communities were metered at that time the effects of the drought would have been less severe due to the lessened wastage of water.

Why Services Should Be Meteerd

There are many good reasons why water services should be metered, a few of which are:

1. It is the fairest way of seiling water, as all customers pay in proportion to their respective consumptions.

2. The water department or company has a pretty good check on the amount of water sold and by comparison with readings of a master meter can better establish losses and leakage and thereby reduce waste in the system in general.

3. Leaks in consumers' service lines can better be located.

4. Knowledge of the various water consumptions is essential in establishing equitable water rates, and the only way in which this information can be obtained and analyzed is by metering of all services.

In some cases, especially in the municipally owned plants, there are certain institutions, such as schools, hospitals and the like, that are supplied with water without charge, and these should be metered and read regularly to get the full benefits of 100 per cent metering.

And here let me digress a little to state that the words "municipally owned" are generally a misnomer, as in the majority of cases the municipality has a large obligation in the form of outstanding bonds, and the only part that is really municipally owned is the amount covered by bonds purchased back, or some such similar item. This is mentioned here because in the municipally operated plants we are so often confronted with the statement that the people own the plant and for this reason they should have all the water wanted for some flat rate that is nowhere commensurate with the cost of producing the water, the fixed charges being lost sight of entirely.

5. It has been proven that as meters are installed that consumers' wastes have been reduced and this in turn effects economies in the amount of power required to pump, if it be a pumping plant, and in treatment costs, which are getting higher and higher every day.

6. As the water requirements of the city are kept within bounds and more or less controlled, the size of the treating and pumping plants and storage and distribution systems are kept to a minimum, thereby keeping capital investment to a minimum, as well as the necessary interest and sinking fund charges, which all result in keeping of the water rates at the lowest possible figure.

7. As the time will most likely come when sewage treatment will become necessary in a good many places, the lowering of the water losses and wastes will redound to the town's advantage in requiring a plant of smaller capacity than would be necessary if water usage and wastage were uncontrolled. Likewise, sewage pumping costs will be less.

With all these reasons in favor of metering, the only ones against it are generally found to be caused by the selfish motives wherein certain customers may want to use unlimited quantities of water without paying a just price therefor. This can be overcome in a great many cases by explanation, and, in spite of the fact that many may be adamant at first, good results are usually obtained.

Another argument against metering is sometimes set forth in that it is claimed that sanitary conditions will not be maintained if water usage be curtailed due to the installation of meters, but it has been shown that for all purposes about 25 gallons per capita per day is all that is absolutely necessary. Under any ordinary rate the cost for this requirement for the average family for an entire month would be modest, in most cases less than the cost of one filling of the gasoline tank of the automobile.

It can therefore be seen that metering is beneficial to both the municipal plant or privately owned company as well as to the consumer, since it contributes a means of compiling equitable rates and keeping bills to a minimum.

Ownership and Location of Meters

Since the type of meter and location of meter setting is governed to some extent by geographical location and local conditions, the remarks that are to follow must of necessity be confined more or less to a particular section and will apply to Virginia.

The ownership and location of the water meter are two subjects on which divergence of opinion exists. In the writer's opinion, the meter should be owned by the water department or company (being charged to capital account) and all maintenance should be done by the owners and charged to operating costs. In Virginia the meter setting just inside the curb line offers so many advantages over other locations that these readily outweigh any disadvantages in the nature of a small additional installation cost, should this be the case. In a good many houses in this section of the country there are no basements in which to locate a meter.

Advantages of Outside Setting

The advantages of outside setting, located in the sidewalk space, are in general as follows:

1. Meter reading is greatly facilitated due to the fact that the reader never needs to wait for a response from the householder on knocking, and should the party be absent it would necessitate making another trip to get the meter reading if the meter were located inside the house. The distance the meter readers have to walk is lessened when outside settings are used, and this in turn permits more meters to be read per day.

2. The meter is always accessible to water department employees for reading, inspecting, testing and repairing.

3. The danger of the meter readers and other water department employees from attacks from vicious dogs is eliminated.

4. The chance of unauthorized persons entering the house in the guise of water works employees is greatly eliminated.

5. Chance of the meter being covered by rubbish, coal, kindling wood, etc., is done away with when the outside setting is used.

6. More accurate reading can be procured when outside settings are used because of better lighting outside than generally exists in basements, under porches or other places where meters might be set.

7. The line of separation between the water department and property owners' liability is clearly defined and there is not much chance of unauthorized connections being made behind the meter.

8. In case of necessity of cutting off the water for non-payment of bills there can be no dispute as to entering the premises if the meter and control are located at the curb line.

9. The outside setting should be in a locked box and, as it is below the ground, is not so apt to be tampered with as would a setting in a more conspicuous place not protected by a box.

10. Less danger of damage to the meter by hot water exists if set at the curb.

11. Danger from freezing is practically eliminated in a well set meter, and in case of fire in the building supplied the meter is not in danger of being destroyed.

In view of all these reasons the writer is of the opinion that the entire meter setting, including the necessary cut-off valve, should be located in the sidewalk space behind the curb line, and that the water department's or company's maintenance and obligations should stop at the customer's side of the meter.

Type of Setting

The following remarks apply to the smaller size meter up to 1-inch, and when larger sizes than this are used the condition must be studied separately and settings made to suit.

It is realized that a properly set meter, although not always the cheapest, will receive more attention in general from the

*From WATER WORKS AND SEWERAGE.
†Field consultant, Virginia League of Municipalities. Former City Manager, Bluefield, Va.

water works operatives and in turn pay higher returns to the department.

It is a good plan to set the meter in a yoke with at least a control valve at the inlet side, although some prefer valves at both the inlet and outlet sides. This does away with the customary curb stop and box.

The meter in its yoke, and with the control valve, should be set in an earthenware, concrete or iron box with sufficient clearance between the risers, if they be used, that the cold ground outside cannot cause the water in the pipes or meter to freeze. A type of box that has proven very satisfactory in our section of the country is one 18 inches in diameter and 24 inches deep, with side slots at the lower end to accommodate the varying depths of the service pipe. The latter, we feel, should be about 24 inches below the ground.

It is important that a lid be provided that fits the top of the box tightly, preferably being locked on with some kind of a locking device. If the lid is fastened on there will be no circulation of air in the box and consequently less danger from freezing. Another advantage is that if the lid is kept on tightly there is less danger of persons tampering with the meter or of pedestrians catching their feet in the hole, with a possible damage suit resulting.

It is also very important that the bottom of the box extend below the maximum frost line so that the warm air from below can rise up around the meter and risers and keep the atmosphere in the box above freezing. In extreme cases it has been found that a smaller tile pipe about 8 inches in diameter put vertically into the ground below the bottom of the regular box (to reach warmer levels) overcame freezing troubles by admitting warmth from below.

Meter Reading

In the writer's opinion, meters should be read monthly, if this is possible, as by so doing a closer touch is kept on losses and wastes, and due to the visiting of each meter every thirty days the stopped meter and other irregularities can be more effectively dealt with. In case a customer has a leak he can be notified within a reasonable time if the meters are read monthly, but if they are read, say, quarterly, the amount of leakage passed will more likely be an appreciable amount and cause some disagreeableness when an attempt is made to collect the bill.

Experiences at Bluefield, Virginia

If you will pardon personal experiences, it may be of some interest to tell how the town of Bluefield recently attacked the problem of setting 700 meters at the rate of something like 100 per week. This was carried on as follows:

A work sketch was first made up and the various kinds of equipment decided on. After the meters, yolks, boxes and covers were ordered out, some figures were made up giving the length of pipe to be cut from the service to allow for elbows, yoke, valve, etc., and the vertical distance that cover, meter, yoke and fittings required was figured and each made into a constant.

Actual installation started with several men digging holes, located from the curb boxes whenever possible, in a certain well defined section so that one foreman could keep all things going. Two men, both of whom had some previous pipe fitting experience, were formed into a "gang" and given instructions how to set the meters, and they then worked together for about a day. These men then were given a helper each and two setting "gangs" were formed and these two helpers were in turn given helpers and four setting "gangs" were formed in a few days. The work was carried through, with as many men as were necessary to prepare the holes ahead of them.

Tools Required

Each of these setting gangs of two men each was furnished with a ratchet die holder and one-half and three-quarter inch dies, a hack saw, two 10-inch Stillson wrenches, a pipe vise attached to a four-legged board, a home-made wooden straight-edge, and a pair of hip boots. The men provided their own rules. The meters, yokes, boxes, covers, pipe, etc., were supplied to the location by a Ford truck. Galvanized nipples of various lengths were purchased and used wherever possible, as they could be purchased cheaper than we could buy, cut and thread the pipe.

When the hole was opened down to the service pipe the meter-setting gang (two men) came along and the first thing they did was to lay the straight-edge across the hole and measure down to the service pipe, and from this the proper "constant," referred to above, was subtracted, which gave the length of risers necessary to bring the top of the meter to the desired point below the meter box lid. If there was a standard nipple of length somewhere near this dimension it was used. If not, the helper would cut pipe to the proper length and thread it. The meter setter in the meanwhile would be cutting a piece of pipe of predetermined length out of the service line and threading the cut ends for elbows. The risers were then screwed in and the yoke and meter set, after which the box was put in the hole. By using a set of specially made hooks the box was easily adjusted around the meters and risers, and the cover put on.

Two men constituted the back filling gang and followed up all setting gangs, backfilling all holes and seeing that the lids were properly fastened.

If the existing cut-off in the service line was so that it could be used to control the water it was used, but if not the meter setter would cut and thread the pipe under pressure, which only took a very few minutes. He would screw the riser pipe with control valve on, bail out the hole, and go on without having to dig back to the main or cut the water off of a section of the town. The water lost amounted to very little.

One foreman looked after the entire job and 700 meters were set at the rate of about 100 per week.

The cost of this work complete, including tools, boots, and everything, was slightly under $19 per setting, which also included the changing of some services where it was necessary.

We believe that in a place where the services are fairly close together one foreman could handle about six meter setting gangs with the necessary hole diggers and could set about 150 meters per week, providing that everything is thoroughly planned ahead.

RENOVATING WATER METERS

Water companies, on the whole, and also several of the more progressive municipally owned water departments, have found that a little dressing up of overhauled meters before returning them to the customers' service has a desirable psychological effect on the customer. The spray gun and gilt or silver lacquer or a combination of the two is the most universally employed method of dressing up old meters after they have been overhauled and tagged "O.K." on the test bench.

Mr. La Verne Trentlage, superintendent of meters in the water department of Elgin, Ill., has evolved a scheme which goes the spray-gilting method one better in making "new" meters out of old ones. In the Elgin scheme the metal parts of the meter are given a treatment which removes the oxidized or carbonated coating from the metal and leaves the parts as metal-bright as when turned out by the manufacturer.

Cleaning and Brightening Procedure

(1) Dip meter parts for 10 minutes in *hot* Trisodium Phosphate solution (2½ lbs. or more of T.S.P. in 10 gallons of water).

(2) Remove meter parts from T.S.P. solution and rinse in *hot* water to remove the alkali.

(3) Dip the parts in Muriatic Acid solution (1 part 18 degree Muriatic Acid to 2 parts of water). Allow to remain in this acid bath for approximately 15 minutes, or longer if necessary. Remove and rinse in hot water.

(4) To brighten to original lustre, immerse in the "bright-dip" solution (1 part 38 degree Nitric Acid, 1 part 66 degree Sulphuric Acid and 1 part water, plus a handful of common salt). Leave the parts in the bright dip for 5 to 10 seconds, the length of time depending on the composition of the metal and degree of brightness desired.

(5) Remove and rinse in *boiling* water to remove acid.

(6) To keep the parts from dulling on standing, a "stabilizing-dip" (especially prepared for this purpose) has been developed by General Chemical Company). After the rinse, the parts are dipped into this solution, removed and allowed to drain and dry.

Notes of Caution: Always add acids to water and *not* water to acids when making dilutions. This will preclude over-heating and spattering of the acid. Be careful to avoid splashing of the acid when dipping the meter parts. In case acid accidentally splashes on hands or face, wash at once in clean water to avoid an acid burn. Spattered acid is also hard on clothing and shoes. Rubber aprons and gloves are good protection.

Do not use iron or steel wire for dipping meter parts. Copper or monel metal wire is satisfactory.

WATER METER MAINTENANCE PRACTICE

As Conducted in Thirty-Six Cities in the United States and Sixteen Canadian Cities

By A P. KURANZ, Superintendent, Water Department
Waukesha, Wisconsin

AT THE request of officials of the American Water Works Association, a survey has been made on "Meter Maintenance Practice" in cities over 30,000 population in Canada and in cities in the United States between 100,000 and 200,000 population. A questionnaire, developed with the assistance of several superintendents, was sent to 21 Canadian cities and 47 United States cities.

Before proceeding further, let me express my appreciation and thanks to every water department and its officials who so enthusiastically responded to the questionnaire. Canadian cities returned 16 or 76.2 per cent, and American cities 36, representing a 76.6 per cent return. The replies came in within a short time after the questionnaires were sent, indicating great interest concerning this subject. Many letters were attached to the questionnaires which gave additional information and encouragement in the work undertaken. It was a distinct privilege and pleasure to be permitted to make this survey and I trust that the answers and the analyses made will prove of some assistance to you.

What the Returns Revealed

Upon studying the returns, it was observed that the ¾ in. meter was usually included with the ⅝ in., so a separate analysis of these two sizes appears to be uncalled for. The 1 in. size was treated very similarly to the ⅝ in. The only great difference being in the registration permitted before meters were removed for testing and renovation. In all other respects the 1 in. meter was grouped with the ⅝ in. and ¾ in., even to the test requirements and cost of repairs. There was not sufficient individual data to warrant repeating the analysis, so this survey deals entirely with the ⅝ in. disc type water meter.

QUESTION No. 1

Do you test all new meters before you put them into service? If you test new meters, what is the lowest flow in G.P.M. at which they are tested, and what accuracy do you demand?

37 cities test *all* meters.
7 cities test from 1 to 25 per cent.
8 cities do not test.

Cities	Rate of Test	% Demanded
1	.04 g.p.m.	75
4	.125 to .2 g.p.m.	90- 98
5	.250 g.p.m.	90- 95
5	.3-.5 g.p.m.	95-102
3	.8-.873 g p.m.	96-102
4	1.0-1.5 g.p.m.	98-102
3	2.0-8.0 g.p.m.	98-102
1	20.0 g.p.m.	98-102
1	1/32 in. orifice	100
6	1/16 in. orifice	98-102
11	1/4 in. orifice	98-102

It will be noted that the majority of the cities test their meters when they are purchased or before they are placed in service. While most cities test their meters, it will also be observed that comparatively few test on the minimum requirements, namely, ¼ g.p.m. Only 11 cities of the 52 test their meters on ¼ g.p.m. or less, including one city testing on 1/32 in. orifice. It appears that most water departments are concerned with proper registration in the class ranging from 0.3 g.p.m. to 1.5 g.p.m. However, surveys available revealing that approximately 12 to 15 per cent of the water passing through a house meter passes at a rate of ¼ g.p.m. or less would indicate that all meters should be tested at the lower flows.

The survey further indicates that there are still a considerable number who use the orifice method of testing, even though the method has become obsolete and is no longer recommended for accurate test.

QUESTION No. 2

Do you remove meters after a certain amount of water has passed through them or do you set a period of time between removals?

Cities	Period Between Removals
11	4.5 to 5 years.
5	6 to 7 years.
4	10 to 20 years.
15	Consumption—stopped—slowing down—complaint.
11	Consumption and time (375,000 to 1,500,000 gallons).
6	No answer.

The survey indicates that there is a definite interest being shown in the problem of having meters returned to the shop for periodic inspection. The period varies greatly and, no doubt, is caused by the action of the individual waters upon the meters. Only a few are permitting the meters to stop or slow down and only one uses the complaint method for removal cause. Eleven of the 52 cities reporting reveal that they use time element and consumption, which apparently is the most efficient way of handling this problem.

QUESTION No. 3

Do you remove meters in a certain section of your city or do you follow the selective manner?

Cities	Method
8	By section of city.
33	Selective.
2	Both.
9	No answer.

Replies to question No. 2 have brought before us the fact that greater attention is being paid to the meter, and the fact that 33 of the 52 cities use a selective means of removal for test further indicates that the meter is not installed and then forgotten.

QUESTION No. 4

How much time per meter is required to bring a meter into the shop?

Cities	Time Required
8	10 to 20 minutes.
6	22 to 28 minutes.
10	30 minutes.
8	40 to 50 minutes.
9	60 minutes.
1	90 minutes.
10	No answer.

The survey shows that there is some variation, but no doubt a more detailed survey of what is involved in the removal of a meter might give us greater knowledge. When 41 of the 52 cities report from 10 minutes to 1 hour, it seems that the time required all depends upon how much additional work is necessary to restore service to the customer after the meter had been removed.

QUESTION No. 5

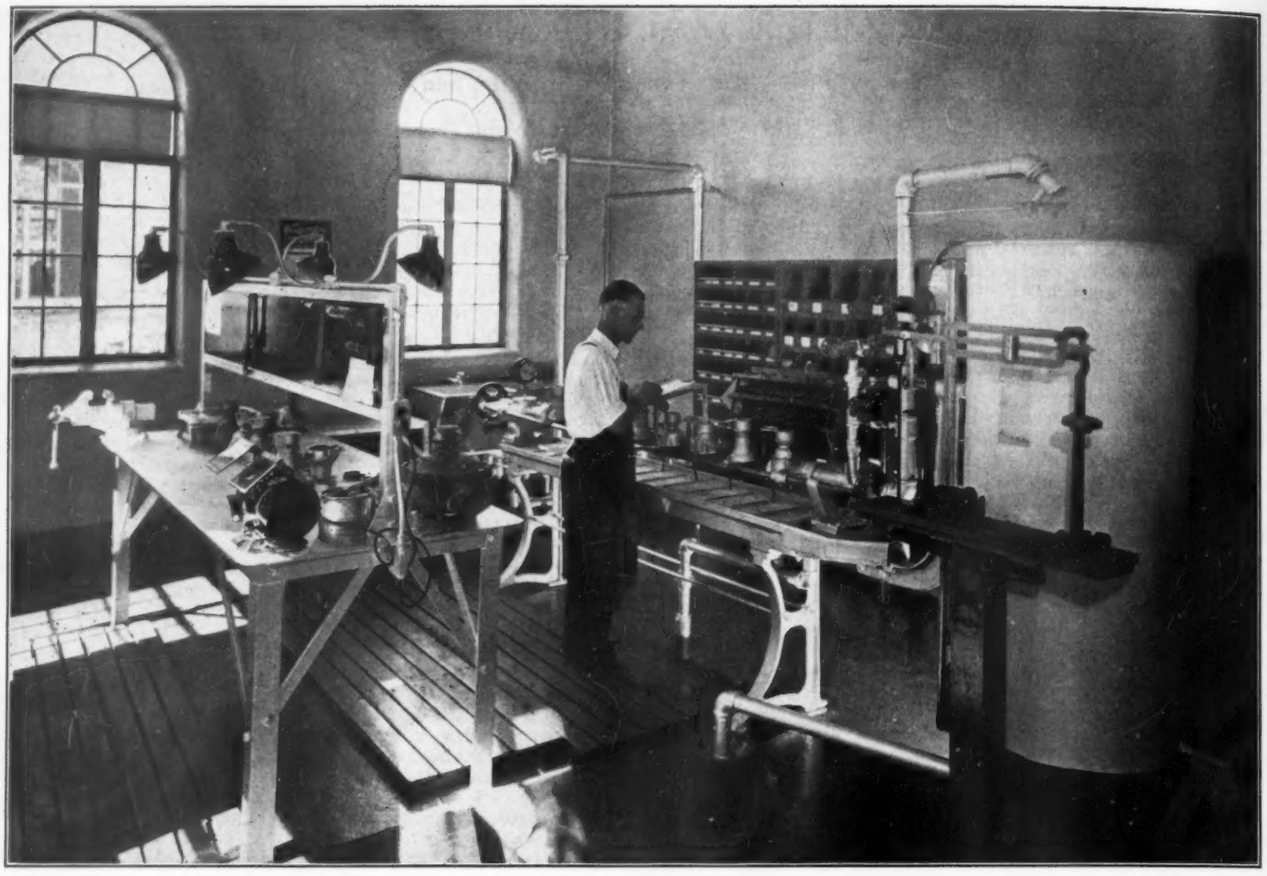
Do you test meters as they are brought into the shop for repairs? If your answer is "yes," what is the lowest flow at which they are tested?

Cities	Answer
37	Yes.
4	On complaint or request.
11	No.

Cities	Rate of Flow
3	.14-.2 g.p.m.
8	.25 g.p.m.
12	.3-1.0 g.p m.
2	1.5-2.5 g.p.m.
3	5.0-8.0 g.p.m.
1	Full flow.
3	1/32 in. orifice.
6	1/16 in. orifice.
2	1/4 in. orifice.
12	No report.

The replies to this question indicate clearly that the manager or superintendent is keenly interested in what his meter has done or is doing under actual working conditions. The second part of the question further indicates this view because quite a number test the meter on a small flow. Again attention is called to the use of the orifice method of testing which has become obsolete.

A report made by the author to the American Water Works Association in Toronto June 26, 1941. It is here reproduced by permission of the Association.



[Recipient of the Geo. W. Fuller Award, Mr. Kuranz was cited.—"For his outstanding work in developing meter testing methods and meter maintenance procedure."—Ed.]

QUESTION No. 6

Do you take the meter apart completely? If you take only part of the meter apart, what part?

Cities	Method
50	Complete disassembly.
2	In part only.
3 (of 50)	take a part only on low test.

From the answers to this question, it is very evident that the utility is concerned about keeping the meter in good repair, otherwise meters would not be completely disassembled.

QUESTION No. 7

What method of cleaning disc chambers do you use?

Cities	Method
31	Use brush, scraper, emery cloth, sandpaper, powder (either alone or in combination).
10	Use brush, scraper, emery cloth and acid in combination.
8	Use acid only.
1	Uses powder and hot water.
1	Uses water only.
1	Uses all methods.

This further bears out the fact that the water department is interested in keeping the "precision instrument" as near perfect as possible. Different waters, of course, will affect the meter materially, some responding to a certain kind of treatment while others are immune to it, but a survey such as this, which covers the United States and Canada, clearly indicates that mechanical means of removing foreign deposit or corrosion is still favored by most cities. Fine emery cloth and sandpaper and brush seem to be the chief implements used in removing foreign material. The small number using acid *only* indicates that departments have discovered that unless one is adept with the use of this material, more harm than good is done.

QUESTION No. 8

Do you repair gear trains by putting in individual gears or a complete new train?

Cities	Method
30	Individual.
8	Complete.
14	Both.

Since practically all meter companies now make the all oil enclosed gear trains, the question has arisen concerning the maintenance of the gear train itself. It appears that most departments still believe that proper repairs can be made by replacing just the worn gears with new ones, instead of replacement of the complete train. However, the mere fact that 8 use nothing but a complete train in repairing the gear train and 14 use both methods indicates that the time element involved in substituting individual gears for the worn ones is an important factor.

QUESTION No. 9

Do you test meters after they are repaired? If your answer is "yes," what is the lowest flow in G.P.M. at which they are tested and what accuracy do you demand?

To the first question, all 52 cities answered "yes." As to the test flows employed the following:

Cities	Lowest Flow Rate
2	.04-.16 g.p.m.
10	.25 g.p.m.
5	.3-.5 g.p.m.
9	.75-1.0 g.p m.
5	1.2-3.0 g.p.m.
3	5.0-8.0 g.p.m.
1	20.0 g.p.m.
3	1/32 in. orifice.
8	1/16 in. orifice.
1	1/8 in. orifice.
4	1¼ in. orifice.

This is one question which was answered in the affirmative by all 52 cities in this survey. However, the rates of flow spread over quite a range, but upon analysis it seems little different than the test requirements on new meters. The question might be asked at this time whether or not flows on repaired meters should be as exacting as those on new. If we analyze the flows on the new meters and compare them with those for repaired

meters, one would be inclined to say that most departments feel that the repaired meters should be as near equal to a new meter as possible. Your attention is again called to the fact that since considerable water is used from ¼ g.p.m. to zero in the average home, that greater attention be paid to the smaller flows.

QUESTION No. 10

How much time per meter does it require to do the work covered in Questions 5, 6, 7, 8, 9? (Bringing meter into shop and testing, taking meter apart, cleaning chambers, repairing gear trains, testing after repairs.)

Cities	Time
9	30 minutes to 55 minutes.
10	60 minutes.
13	70 minutes to 90 minutes.
4	120 minutes.
6	150 minutes to 210 minutes.
10	No report.

Here again we find quite a variation. It can no doubt be explained that different operations are included and considerable time variation would be found in cleaning up the chambers as well as repairing the gear train. On the other hand, a majority of the cities seem to spend, roughly, 60 minutes per meter.

QUESTION No. 11

What is the cost of repair parts ONLY based on a meter year basis? (Example: Cost of repair parts, $2 80. Meter removed every seven years would mean that 40 cents per meter per year is the actual cost of repair parts only.)

Cities	Cost
1	$ .008.
10	$ .06-.15
5	$ .20-.29
7	$ .30
4	$ .345-.37
6	$ .427-.48
3	$ .50-.66
1	$1.22
1	$ .38 parts and labor
14	No costs reported

Since all types and makes of meters are included in this survey, there may be a reason for the widespread difference, but it is believed the most important cause for this difference is the action of the water on the meter, which, in turn, necessitates a difference in time period between the removals for test and repairs. Several factors enter into this problem, so when analyzed from every angle, the discrepancy may not be as great as it seems.

QUESTION No. 12

At what cost of repair in relation to the cost of a new meter do you feel it uneconomical to repair meters?

Cities	Cost of Repair (Per cent)
3	30 to 40.
20	50.
4	55 to 66⅔.
7	75 to 90.
7	Do not scrap.
11	No answer.

Here there seems to be quite a general accord on what the answer should be. Nearly one-half of the cities reporting indicate exactly 50 per cent. Most of them say between 30 and 65⅔ per cent. No doubt the time element required to make repairs is balanced against the cost of the repairs and the improved registration resulting.

QUESTION No. 13

When meter is repaired, do you set the register back to "zero" or keep a continuous record of the total registration?

Cities	Method
28	Continuous.
28	Set back to zero.
3	Both.

The answers to this question seem to have little bearing on the efficiencies of the meter, but it does indicate that careful records are kept by most departments as to the performance of the individual unit.

QUESTION No. 14

What percentage of the water pumped is accounted for through meters?

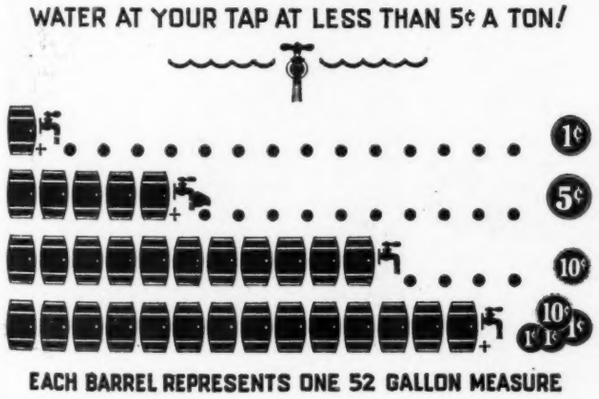
The answers to this question varied so greatly that only by referring to notes and letters attached could comparison be made. Since cities are not all 100 per cent metered, no fair figures can be obtained. Many apparently have no master meters because some have gravity systems and therefore are little concerned as to the supply. However, those cities which are 100 per cent metered and which have adopted a good meter maintenance practice plan account for a large percentage of the water pumped. No figures will be given because a survey would have to be made of cities having all services 100 per cent metered.

Conclusions

In summarizing the entire matter, at least one statement can be made without fear of being contradicted. That is where a city was found to have all its services metered and a carefully planned system of testing, repairing and cost recording, that city also enjoyed the distinction of accounting for a high percentage of the water pumped. One case is outstanding. The ten-year average of accounted for water through meters is 88.2 per cent, and the analysis made of this questionnaire clearly indicates that this city is very exacting as to testing, repairs and cost account of its meters. So often the water utilities install a meter and then proceed to forget that it really is a "precision instrument." If carefully watched and properly repaired and tested, it will more than repay you for the time and effort spent. It will be the instrument that will tend to keep your finances in proper balance. Too much stress cannot be placed upon the value of a proper meter maintenance program in your city, which program should include the following:

1. Test all meters when purchased.
2. Remove them after a certain time period or time and consumption combined.
3. Test them when brought into the shop for repair. Keep a record of these tests.
4. Repair carefully, especially chamber and gear train. Keep a record of repair costs, including labor.
5. Test after the repairs. Require a high percentage of registration on ¼ g.p.m. flow.

If you will do that, you will notice a distinct increase in your revenues. *Ask those who have followed this plan.*



[The above has been used by the Los Angeles Water Bureau to stress the cheapness of water at 11 barrels for a dime and no haulage to pay.—Ed.]

WHAT LEAKS COST

SIZE OF OPENING	AIR		STEAM		WATER	
	Number of Cu. Ft. Wasted per Month 100 Lbs. Pressure	Total Cost of Waste per Month @ 10c per M Cu. Ft.	Number of Lbs. Wasted per Month 100 Lbs. Pressure	Total Cost of Waste per Month @ 60c per M Lbs.	Number of Gallons Wasted per Month 40 Lbs. Pressure	Total Cost of Waste per Month @ 16½c per M Gals.
1″/2	17,798,400	$1,779.84	805,000	$483.00	1,231,000	$192.00
3″/8	9,979,200	997.92	460,000	276.00	692,400	108.00
1″/4	4,449,600	444.96	203,000	121.80	307,700	48.00
1″/8	1,114,560	111.46	50,500	30.30	76,900	12.00
1″/16	278,640	27.86	12,750	7.65	19,200	3.00
1″/32	69,552	6.96	3,175	1.91	4,800	0.80

Courtesy M. B. Skinner Co

A SMALL METER SHOP

Room Built and Equipped for the Needs of a Department With 3200 Metered Services at Cost of $1500

By ROGER W. ESTY

Water and Sewer Board, Danvers, Mass.

THE Town of Danvers is situated in the northeastern part of Massachusetts, has a population of 15,000, and is a farming and industrial community, with considerable historical background.

The water system, started back in 1876 with some twenty miles of pipe and about 500 services, today covers 67 miles and has 3,200 metered services. Our consumption started off with about 120,000,000 gallons per year and increased to an annual consumption of 550,000,000 gallons during the 1920's. Metering, which was begun in 1922, has caused water waste and total consumption to drop some every year until now Danvers uses only about 360,000,000 gallons annually.

For years, while our consumption was decreasing and our metering was increasing, our revenue kept increasing until it became permissible to reduce our service charge 20 per cent. Later the meter rate was cut 25 per cent, and it will be necessary in the very near future to again reduce our rates.

All of this is the result of planned metering. Up to two years ago we had no meter testing room in which to test, store, and maintain our meters. Most of our meters—70 per cent—have only been in about five years, and we felt it was becoming necessary to build and equip a modern, up to date testing room to properly maintain them.

Our Compact New Meter Shop

Well, what is different with our testing room than what you may have? It may be different in one respect, and that is, we are starting off with everything new. Three years ago we were planning for a new shop building but it just didn't materialize, so the Board decided that they would build and equip an up to the minute meter room within our present shop building. For the purpose $1,500 was voted to equip it.

Outside of our commercial meters we only had about 1,000 meters from 1922 to 1934. Then we started to install a few hundred each year until we had 3,200 meters in service by 1938.

The pictures accompanying this article illustrate our present set-up which we feel meets our needs in a satisfactory and efficient manner.

The room is 21 feet 3 inches long by 11 feet wide with Homasote wallboard walls, stained hardwood floor, three windows equipped with venetian blinds and two doors. So, first of all, it is light and airy. For artificial light it is lighted by fluorescent lights.

We installed a three meter Ford testing machine and Ford's Testerate device, which regulates the testing flow in gallons per minute, a 10 cubic foot tank and 1 cubic foot tank.

In the corner of the room, between the meter testing machine and bench, we constructed a wooden washing sink, which is 3 feet 4 inches by 1 foot 8 inches by 36 inches high.

Our bench is 12 feet 4 inches and 2 feet 5 inches wide and is 3 feet high. It is constructed out of oak and is covered with a steel top. It has a meter-holder on the end over the sink, where the meters are taken apart, and a small vise is located near the same end. At the other end is a portable drill press and a portable grinding and brushing machine.

Under the bench top near the sink is a drawer for the every day tools. Then an empty space to sit before, so your legs can go comfortably under the bench. Under this section is our air line hose coming in from the garage. We find the air hose a highly important and useful part of meter shop equipment because it is very essential to have air to properly clean and dry out the disc chamber for proper fitting. Also air is useful for operating a meter for any purpose, particularly the "running in" of discs.

Storage Shelves

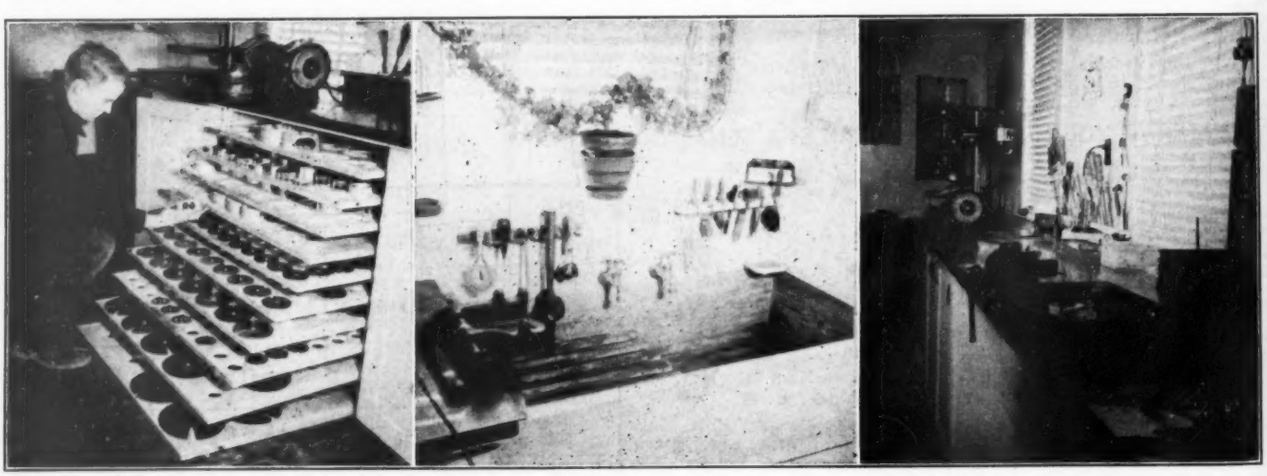
Then we have what we call our "bakers wagon shelf-storage," a series of shelves, grooved and slotted to hold gear trains, registers, covers, discs, and chambers. This is the finest method of storage that I have been able to find or devise. With this scheme many supplies can be stored in a very small space.

The next section is made up of three drawers for miscellaneous storage, equipment, and tools.

Secord File Handy in Shop

At the end of the bench is sufficient space for a steel desk which contains a card file of all of the meters. These record cards show a complete meter history as to where and when installed, when the meter has been taken out to be tested; also the results of the tests, with a list of all material used in making changes or repairs. This desk also serves as a place to do the necesary book work by the meter-man and a place to keep his test books, etc.

Along the other side of the room are three sets of steel shelving which is ample storage for all active meters. That is, those

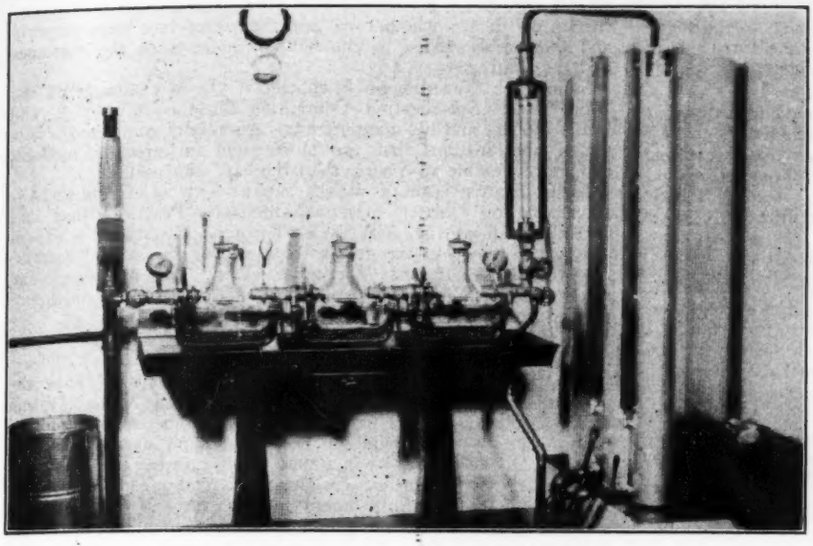


Views of the Danvers Meter Shop

Convenient method of storing meter parts. We call it our "baker's wagon," after which it was patterned.

The wash-sink in a corner; meter holder for dismantling; cleaning gadgets and handy roll of paper towels. The ivy adds a touch.

Work bench with record file and desk in corner. Portable drill press, grinding and brushing machine—and plenty of tools and light.



Our Three-Unit Ford Testing Machine
Equipped with flow indicating "Testerate" unit, above, discharging into calibrated 10 cu. ft. and 1 cu. ft. measuring tanks. This set up is a "honey."

brought back from summer service for winter storage, and from houses where service has been discontinued for an indefinite period. There are seven shelves, each supplying space to store 250 meters.

We read all of our meters by districts, as we have the town divided up into A, B and C sections, and so we have assigned Section 1 for meters in District A, and Sections 2 and 3 for Districts B and C.

All inactive meters are stored away in another room, which leaves this room entirely for active material, which plan makes for better "housekeeping."

At the end of the storage racks we have a cabinet of ten drawers, all divided up

DANVERS WATER WORKS

Make .....

..... Number ..... Order No. .....

..... Reading B. T. ..... Acct. No. .....

..... St. Reading A. T. ..... Tap No. .....

Date Tested .....

Number of Cubic Feet	Discharge G. P. M.	PRESSURE Inlet	PRESSURE Outlet	%	REMARKS

..... 194 ..... Inspector

Meter Test Record Form

DANVERS WATER WORKS

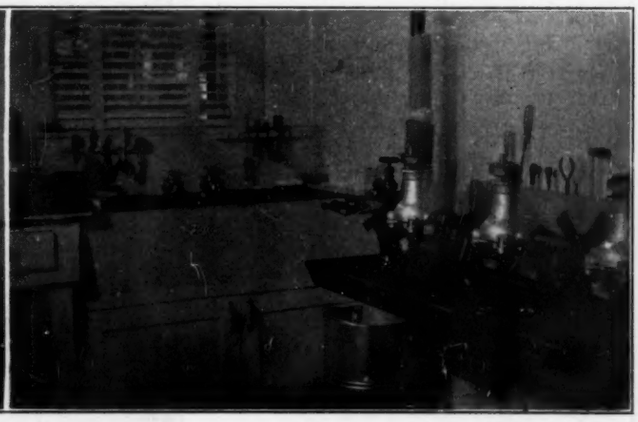
Name .....
Address .....
Size & Make .....
Number .....
Reading .....
Date .....
Remarks .....
.....
By .....

DANVERS WATER WORKS

Name .....
Address .....
Size & Make .....
Number .....
Reading .....
Date .....
Remarks .....
.....
By .....

Meter Record Card and Stub

Looking "aft" down the bench. A close look will reveal the highly useful air hose at the central working space.



Another look at the "wet-end" of the room. Wash-sink, with storage beneath, and the Ford testing machine.

Two More Views

into small compartments, which holds the small parts of the registers, gear trains, discs, etc. Over our bench we have three sets of very small drawers, which hold several sizes of change gears and some parts of the discs and gear trains.

This description, I feel, will give a pretty good idea of what we feel a well fitted meter testing room should have, to test and maintain 3,000 meters. The only difference that I can see between what we have and a city having, say, 7,500 meters would be: first, a testing machine of greater capacity; second, a little larger bench; and third, additional storage facilities.

Design to Save Steps and Loss Motion

Make your room cozy, don't make it too barny. Arrange the testing machine, washing basin, and repair bench close together. It saves time and steps, steps—and this is very important. I have seen meter rooms in which the meter man spends far too much of his time walking back and forth and back and forth from one operation to another.

Our meter room is the result of my observations in a great many other water plants and from the many helpful suggestions we have received from superintendents and meter-men who actually do the testing. I am indeed very grateful to them, and I extend an invitation to all water works men to visit or meter room, for it may offer some thought or suggestions toward even a better set-up than we have here at Danvers.

In my travels, interviews and correspondence there seems to be no fixed standard procedure in testing, and, furthermore, no one in authority (like a sealer of weights and measures) ever checks up to see whether or not the meter has been properly and thoroughly tested to the mutual interests of the customer and the utility.

Samuel F. Newkirk of Elizabeth, N. J., is chairman of the Joint Meter Specification Committee for the A.W.W.A. and N.E.W.W.A., and his committee has essentially completed a new set of specifications that are more rigid in certain directions, and more flexible in others, than those of the past.

In the August issue of WATER WORKS AND SEWERAGE there is an article on "Water Meter Maintenance Practice" that was recently read at the A.W.W.A. Toronto convention, which is very timely. It is the result of a survey by A. P. Kuranz, Superintendent of the Waukesha, Wis., Water Department, made to secure a cross-section picture of meter maintenance policies and practices in this country.

Why Not "Standards of Testing Procedure"?

The thought has occurred to this writer—why not have the present committee also develop "Standards of Meter Testing Practice," to serve as a pattern in equipping meter-test shops of various sizes, and a guide in the proper and most dependable procedures and operations in actual routine testing practice? To the writer, at the time of designing and equipping the Danvers meter-room, and to many others contemplating new meter shops or revamping existing ones, such a guide would prove of high value and usefulness. It will also go far toward bringing standardization and better practices into the important field of metering, where there appears to be room for much improvement and a real need for standardization.

ELECTRIC HEAT SOLVES PROBLEM AT PUMPING STATION

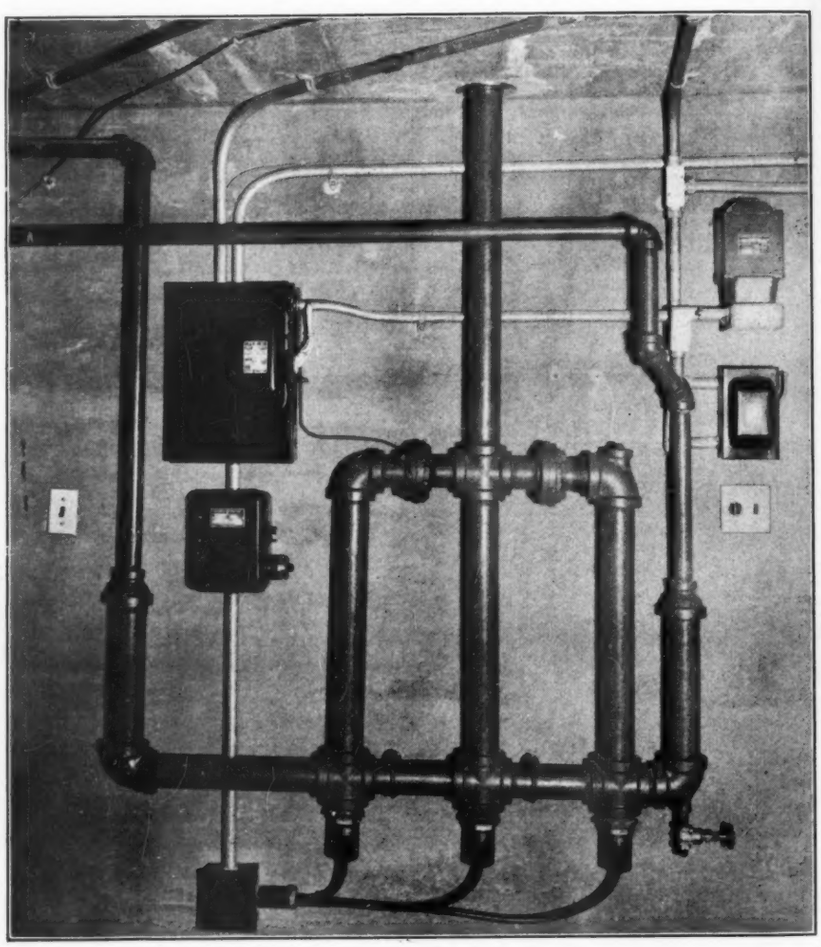
ELECTRIC heat proved the answer to a heating problem recently presented at the plant of the South Bay Consolidated Water Co. at Bayport, Long Island. This pumping station contains two rooms on the ground floor and a basement. One of the two ground floor rooms serves as an office, and the other is the chemical feeder room, separated from the first by a brick partition.

Since the chemicals stored in this second room are of a nature to attack almost any metal except cast iron, it was decided that the best method of heating the room would be by using cast-iron radiators. It was decided to build an immersion heater "electric furnace" in the basement to supply hot water to the radiators in both first floor rooms.

Three G-E electric water immersion heaters are used to heat the water in this ingenious furnace. The hot water riser leads from the top of three heater-enclosing pipes to the radiators on the main floor. The returns lead back to the bottom of the furnace, providing a neat, compact circulating system. An expansion tank is connected to each of the radiators in the first floor rooms. The radiator capacity is so arranged that the expansion tank can take care of the water expansion under any operating condition.

A magnetic contractor handles the heater load, and is controlled by a thermostat located in the operating room above.

A very clear view of this "furnace," with its electric and water connections, is shown at the right.



"METER CRADLE"

Handy Gadget in Repair Work

By DON CALDERWOOD, Engineer
Pennichuck Water Works
NASHUA, N. H.

THE accompanying sketch and snapshots show a meter shop "gadget" that we designed and had fabricated in a local blacksmith shop.

This device not only speeds up the meter repair work but it also eliminates jammed fingers and skinned knuckles. The "U" part of the yoke should be covered with a piece of soft sheet lead to protect the threads of the meter spuds. We also found it advisable to bend another piece of lead around the two bottom bars from yoke to yoke.

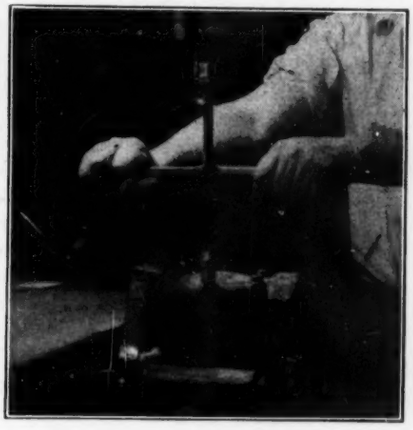
The dimensions (given on the sketch) were worked out to fit almost any make and size of meter up to and including the one inch size. If any water works is fortunate enough to have only one make of meter, or largely one make, in service it is quite possible that slight modifications can be made to better suit the needs of that particular shop. With the sketch to follow no further description seems necessary, but the writer will answer any questions.

After the repairs are completed the gadget can be slid out from the under bench clamps and hung somewhere out of the way.

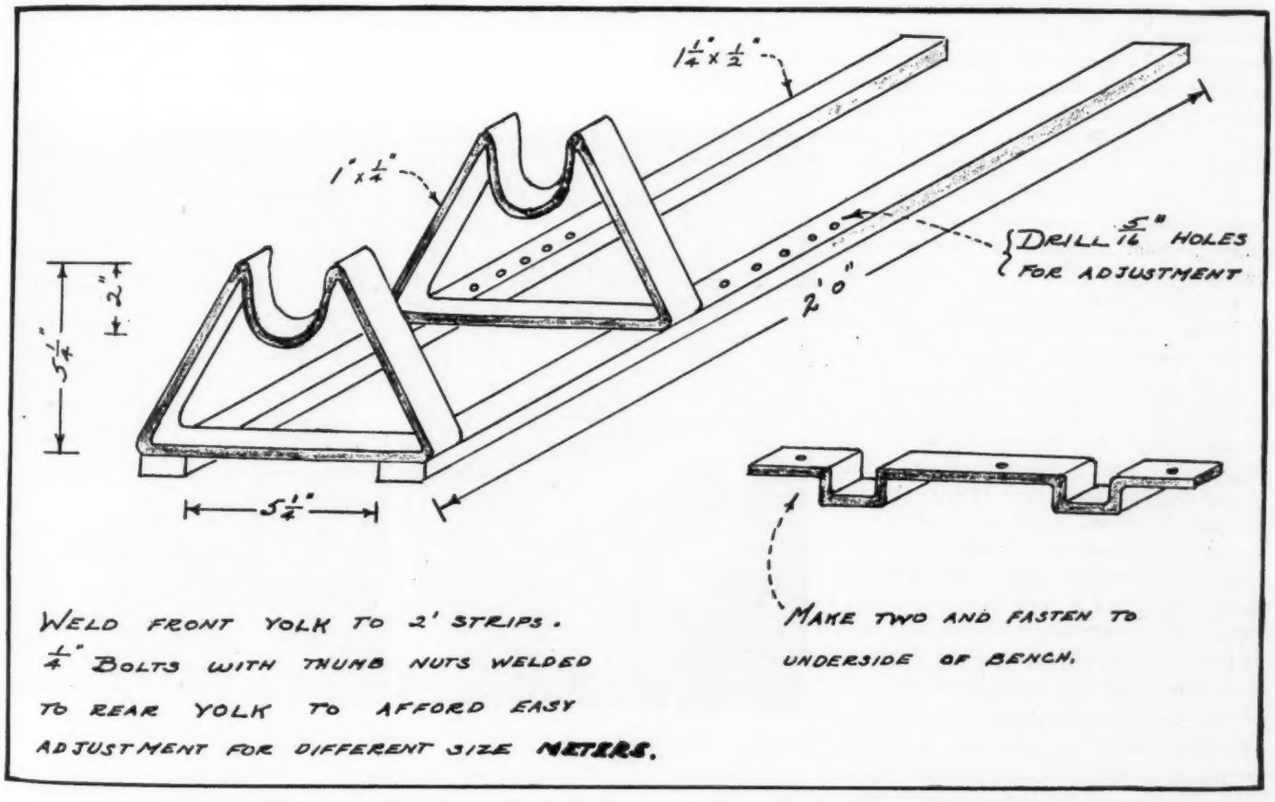
In connection with this gadget we developed a handy socket wrench. It is similar to the type of wrenches used in garages and filling stations to remove tires and wheels from an automobile. We first selected four sockets that fitted the various sized nuts of the meter casing bolts, then had these sockets welded to a + made from ½" steel rod.

Just another case where an investment of a few cents saves money, time, dispositions. And, in instances nicks in the shop man's anatomy.

"Meter Cradle" in Position
(Note protective lead coverings)



—And in Use
(Featuring the handy socket wrench)


1¼" x ½"
1" x ¼"
2"
5¼"
5¼"
2'0"
DRILL 5/16" HOLES FOR ADJUSTMENT
WELD FRONT YOLK TO 2' STRIPS. ¼" BOLTS WITH THUMB NUTS WELDED TO REAR YOLK TO AFFORD EASY ADJUSTMENT FOR DIFFERENT SIZE METERS.
MAKE TWO AND FASTEN TO UNDERSIDE OF BENCH.

Shop Sketch of Nashua "Meter Cradle"

MAINTENANCE OF LARGE METERS IN THE FIELD

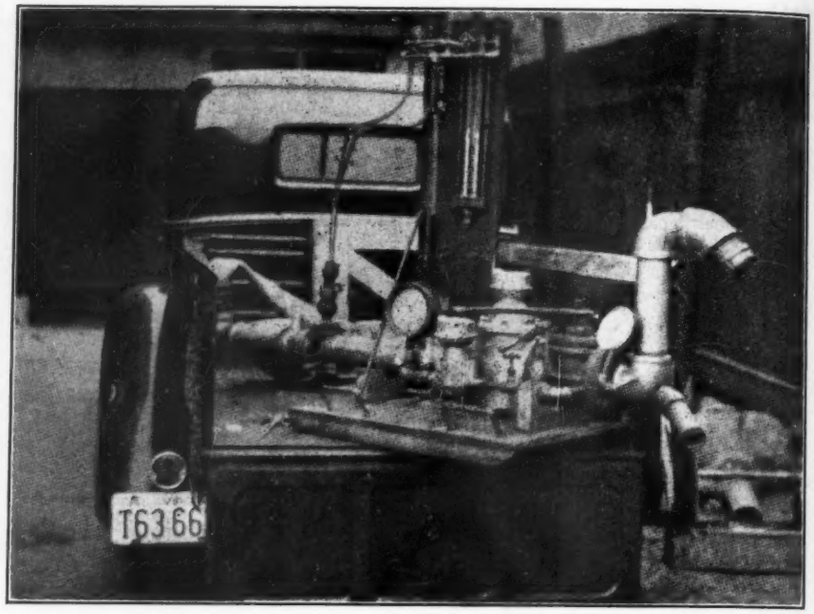
By D. R. TAYLOR, Plant Superintendent
Roanoke, Virginia

WHILE most discussions of meter maintenance have laid stress principally on domestic meters, the maintenance of larger commercial and industrial meters is of considerable importance. Although large meters may account for only a minor portion of the total revenue, underregistration of these meters to any great extent may constitute a major factor in the accounting for input into the distribution system and water used.

Large industrial consumers may be furnishing only two per cent of your total revenue, yet using ten per cent of your total consumption through a meter that is forty per cent slow in registration. Besides the monetary loss in such a case, the daily quantity not registered may amount to several per cent of your total input or several hundred thousand gallons per day. We have seen such an existing condition blandly ignored, or at least passively tolerated, by those who would break a hamstring to get a gang out to stop a small service leak at night rather than let it run harmlessly until morning. The average water works superintendent will expend any amount of effort and money necessary to stop a leak in his distribution system; yet, many of them display a surprising degree of apathy towards checking the registration of large meters where a correction may pay even greater dividends than in stopping a main leak. We, at Roanoke, have followed a carefully supervised meter maintenance program for almost ten years, and our records show that we are receiving dividends in the form of increased revenues as a result of such a program amounting to several times our annual cost of such maintenance.

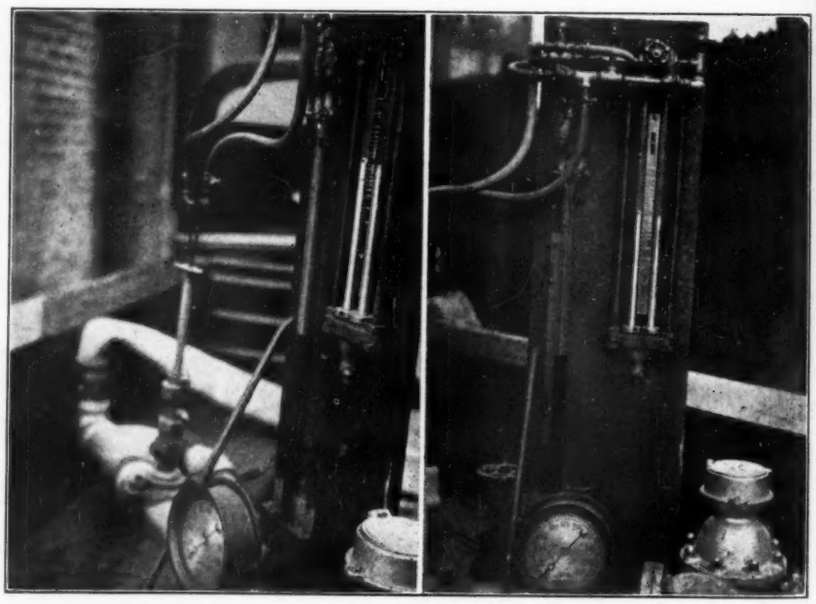
Some capital expenditures are of course necessary at the beginning of such a maintenance program for the installation of test tees and by-passes if these were not included in the original installation. It will also be necessary to provide a test meter, which can be purchased complete or assembled at your shop. Ours, shown in an accompanying photograph, consists of a three-inch current type meter and a 5/8-inch disc type meter with special test dials, proper valves, connections and accessories which will be explained later.

The case of the current type meter is of silicon-aluminum, to eliminate as much weight as possible, and was especially made for us by one of the leading meter manufacturers.



Field-Test Meter and Accessories

A 3-in. current type and 5/8-in. disc type meter, the case of the former being of silicon-aluminum to reduce weight. Note the pitot-rod and manometers for flow rate control.



The Pitot Rate Indicator Attached to the Test Meter Unit

On left is seen the pitot rod and dual manometer for high and low pressure testing. On right is better shown the method of connecting the carbon-tetrachloride and mercury manometers, also the etched brass plate indicating in gals./min direct.

CHART 1

TEST RATES—G. P. M.

(Standard for Roanoke Meter Tests)

Type	Size Inches	Gallons per minute—Min.	1st	2nd	3rd	4th	5th
Disc	1½	1	1.5	6	40	80	...
	2	1	1.5	6	40	100	...
Compound	1½	.25	1	5	40	80	...
	2	.25	1	5	40	80	100
	3	.5	1	6	40	80	150
	4	.5	1	6	40	80	200
	6	.5	1	6	40	80	250
	8	.5	1	6	40	80	300
Protectus	3	1.5	2	6	40	100	200
	4	1.5	2	6	40	125	200
	6	1.5	2	6	40	125	250
	8	1.5	2	6	40	125	300
Detector	3	1.5	2	6	40	125	200
	4	1.5	2	6	40	125	200
	6	...	4	10	40	125	250
	8	...	4	10	40	125	300
Current	1½	5	...	10	40	80	...
	2	7	...	10	40	80	150
	3	10	...	20	40	100	200
	6	15	...	20	40	100	250
	8	30	...	..	40	100	300

Experience in Method and Frequency of Test

The frequency of testing large meters depends upon the corrosiveness of the water measured and the monthly consumption through them. With one hundred and ninety large meters from one and one-half inches to eight inches in size, our experience shows that the economic frequency of test in our plant is once per year for all types except discs, and every three years for those. We also learned early that the old method of testing with various size orifices, without regard to actual rates of flow, was entirely inadequate and was apt to lead to false interpretations of the records. For instance, three different six-inch Protectus meters may be tested at three different locations with a one and one-fourth inch orifice. Differences in elevations may result in full flow pressures we will say of twelve, twenty-four, and thirty-six pounds per square inch respectively at the three locations. This means that one meter has been tested at a rate of 110 g.p.m. (below the change over point), one at 160 g.p.m. (exactly at the change over point), and one at 200 g.p.m. (above the change over point). It is obvious that, while these three meters were not only of the same size but also of the same manufacture and tested with the same size orifice, the three tests are not comparable. Hence the necessity for standard testing specifications and methods.

Standard Test Rates Established

We devised standard test rates for all meters, as shown in Chart 1.

We next installed a 750-gallon steel tank on our pumping station grounds and calibrated it with a ten-gallon tested measuring can. This tank is buried in the side of a hill in such a position that the small truck carrying our test meter can be driven close and over it, so that the test meter can be easily and quickly tested volumetrically. After calibrating the test meter, we calibrated each of the orifices with the test meter. These results were first plotted on logarithmic graph paper as shown by Chart 2.

From Chart 2, we made up for use in the field Chart 3, which reveals the delivery of the several orifices at various pressures.

A Pitot Rate Indicator

We installed a pitot rod through a corporation stop in the three-inch inlet pipe of the test meter and ten-diameters ahead of it. (The make and coefficient of this pitot rod being unknown, it had been discarded; however, this knowledge is not necessary for its present use.) Two manometers were mounted on a board on the test meter base in such a position that the operator can observe them while he operates the discharge valve—see cut. These manometers can be inexpensively made with boiler gauge glass sets.

The two manometers are connected with rubber tubing and proper valves, so that either can be operated independently by the one pitot rod. One manometer contains carbon-tetrachloride, with a specific gravity of 1.60 for low rates of flow, and the other contains mercury with a specific gravity of 13.58 for the higher rates of flow. The pitot rod and each of the manometers were then calibrated with the test meter, and the results plotted as shown on Chart 4.

From this chart, brass scales were made for each of the manometers by marking on narrow brass strips the rates in gallons per minute indicated by various deflections of the manometers. The operator therefore opens the discharge valve (a plug type has been found more satisfactory) until the deflection in the manometer indicates any desired rate as shown on the scale.

Rates from .25 g. p. m. to 6 g. p. m. through the five-eighths inch side of the test meter are too low for measurement by either manometer, yet are low enough to be easily obtained and controlled by a needle valve, orifices and a pressure gauge in accordance with Chart 3. Rates from 10 g. p. m. to 120 g. p. m. may be controlled by the carbon-tetrachloride manometer, and rates from 80 g. p. m. to 400 g. p. m. may be controlled by the mercury manometer. This outfit has performed very efficiently and economically for the last two years.

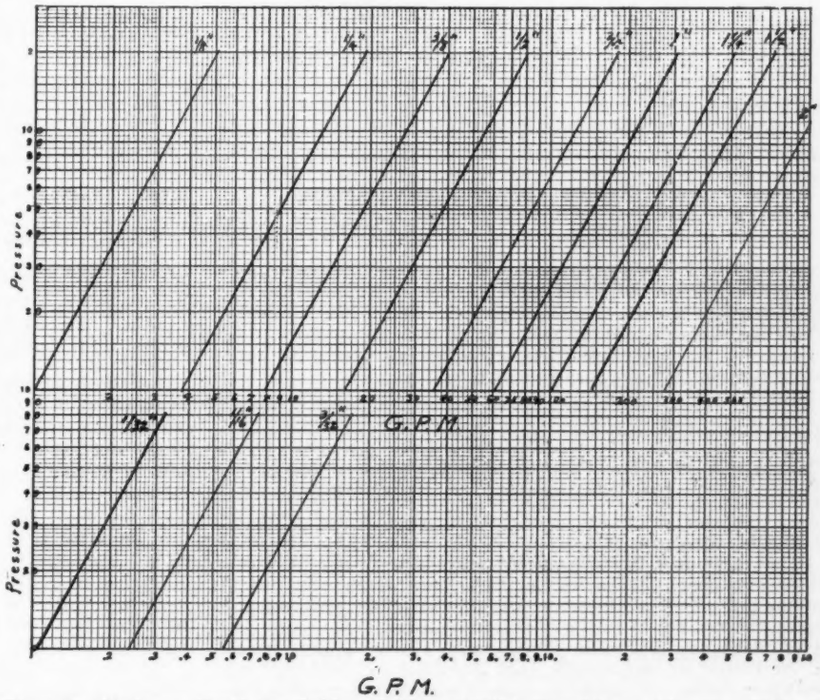


Chart 2—Discharge Graph for Orifices Calibrated With Test Meter. (See also Chart 3.)

CHART 3

FIELD CHART

(Gallons per minute)

Orifice Size	Pressures .25	.5	1	1.5	2	4	5	6	7	10	15	20	30	40	80	100	125	150	200	250	300
1/32 inch	50	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1/16 inch	11	40	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
3/32 inch	..	9	30	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
⅛ inch	..	..	10	21	36	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
¼ inch	..	..	..	..	..	11	17	24	32	60	..	..	..	..	..	..	..	..	..	..	..
⅜ inch	..	..	..	..	..	..	..	..	8	11	34	56	..	..	..	..	..	..	..	..	..
½ inch	..	..	..	..	..	..	..	..	..	..	9	10	32	55	..	..	..	..	..	..	..
¾ inch	..	..	..	..	..	..	..	..	..	..	..	..	7	13	46	..	..	..	..	..	..
1 inch	..	..	..	..	..	..	..	..	..	..	..	..	..	..	17	26	38	54	93	..	..
1¼ inches	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	15	21	36	54	77
1½ inches	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	11	19	29	40
2 inches	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	12

To those who are interested in constructing such an outfit and find it necessary to purchase all parts new, we would suggest that they also investigate the Henszey Flow Indicator. This instrument may be cheaper than a new Pitot rod and manometers and will probably give results equally as satisfactory.

The purpose of this discourse has been to show the fallacies in the use of the old methods and the advantages of other methods of testing large meters on standard rates according to size, so that the results are comparable and can be properly and advantageously interpreted and analyzed.

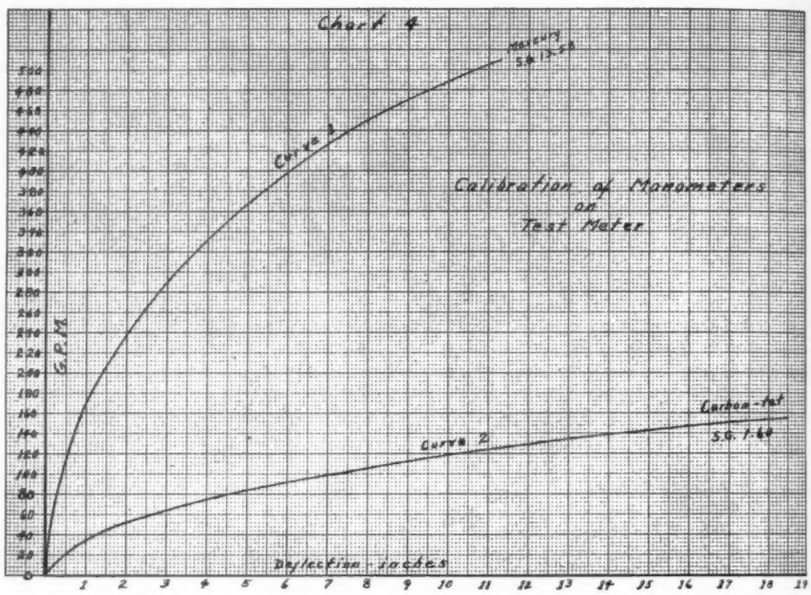


Chart 4—Calibration Graph Made on Manometers (From which the brass scales were prepared.)

PAINTING DAMP WATER PIPES

In reply to a question regarding the painting of plant piping which is wet from condensed moisture and cannot be taken out of service long enough to dry, The New Jersey Zinc Company prints the following in its periodical, "Paint Progress." The engineer, by the way, stated that wiping the pipes with dry rags before painting had not been satisfactory.

Says New Jersey Zinc:

"We have seen good results obtained by using a turpentine wash to replace the moisture on the pipes and have, as a result, adopted the following method in our own plants:

"The surface is prepared for painting by removing the loose paint and scale by wire brushing and scraping. The dirt and excess moisture are then wiped off the surface and a liberal coating of turpentine is applied.

"The turpentine has a two-fold effect: first to replace the water remaining on the surface by virtue of its preferential wetting property, and second, to 'lift' any loose rust scale remaining on the surface after the mechanical cleaning. A primer coat of standard Zinc Dust-Zinc Oxide paint is then applied directly on the turpentine wet surface, thus providing the necessary rust inhibitive coating. In actual practice, a considerable interval may be allowed between the application of the turpentine and the primer, since the turpentine prevents further condensation of water on the steel.

"Brush application of the primer is preferred to spray application, since it insures the intimate contact of the Zinc Dust with the surface. An 80:20 Zinc Dust-Zinc Oxide formula with a linseed oil vehicle has been used, but a synthetic vehicle, such as phenolic, may be preferable, first, because of the more rapid drying of the synthetic resin formulation, and second, because of the improved water resistance of the film.

"The usual drying interval is allowed, after which the finish coat paint is applied. Just before the application of the second coat, the moist surface is again wiped with turpentine, but care must be taken to avoid an excess of the turpentine, since it might soften the surface of the primer.

"Either an 80:20 Zinc Dust-Zinc Oxide paint or other suitable metal paint may be used as the finish coat. Colored Zinc Dust paints are available for finishing coats where a distinctive color scheme is desired.

"It has been found that kerosene may be substituted for turpentine to replace moisture on the pipes, but its action is much slower and its assimilation into the paint less positive."

STREAMLINE PIPE AND FITTINGS DIVISION MUELLER BRASS CO.

Port Huron, Michigan

STREAMLINE Copper Pipe and STREAMLINE Solder Fittings for Water Service Work

In 1924 the Mueller Brass Co. originated and were the first to introduce a product then known as Mueller Copper Service Pipe and Flared Fittings. This was a distinct innovation and was conceded to be the most revolutionary contribution of the time for water service purposes.

Waterworks' engineers and superintendents prefer as soft copper pipe as possible for water service work. STREAMLINE Type K Pipe is consistently and uniformly soft. It is made from Virgin Copper Ingot consisting of at least 99.94% copper and throughout every phase of its manufacture is under rigid and constant laboratory control. From the time we started to manufacture this product in 1924, and throughout the years since, we have produced the best and softest pipe that can be made for water service work.

RUST PROOF

STREAMLINE Copper Pipe is rust-proof and is superior to any other metal for service pipe work. Under normal conditions of soil and water, it will last for generations, and will deliver its full capacity of water free from foreign particles as clear and pure as it is in the water main.

FLEXIBLE

STREAMLINE Copper Service Pipe is exceptionally and uniformly flexible. It can be very quickly and easily bent around comparatively sharp radii without annealing or loading. It may easily be bent around obstructions encountered in the trench with a great deal less cost than would be entailed in removing the obstruction.

REASONABLE COST

Copper Pipe connected with STREAMLINE Fittings is very reasonable in cost, although naturally a little more expensive than rustable pipe. It really costs a great deal less over a period of time, because replacements are eliminated owing to the rust and clog-proof properties of STREAMLINE Type K Copper Pipe.

COUPLING
Copper to Copper

VIBRATION PROOF

STREAMLINE Copper Pipe connected with STREAMLINE Solder Fittings is free from the harmful effects of vibration. Vibration is not localized at the joints as it is with threaded or flared fittings, but is harmlessly dissipated throughout the service line.

PERMANENT

STREAMLINE Copper Service Pipe is permanent. Once installed it may practically be forgotten; it will give no future trouble. For years it will continue to give the same uninterrupted service and undiminished flow of water.

COUPLING
Copper to Iron

SETTLEMENT AND FROST ACTION

STREAMLINE Copper Service Pipe is so ductile that it will stretch enough to easily take care of any settlement of filled earth, or, in fact, anything that might impose a strain on the service line which would cause failure of rigid ferrous pipe or, at the very least, cause leakage at the threaded connections.

TEE

In the Northern States and in the Dominion of Canada, copper service pipe of our manufacture has an outstanding advantage that places it far in advance of any other service material. This advantage is its resistance to frost action. This service pipe containing water under almost any range of pressure used in water service work can be alternately frozen and thawed out for a considerable number of times without showing any effect except a slight increase in diameter.

STREAMLINE SOLDER FITTINGS

The STREAMLINE Solder Fitting is connected to the pipe by feeding solder through a feed hole in the fitting. Capillarity causes the solder to thoroughly bond the pipe to the fitting and produces an enormously strong joint. This joint is so strong that if, for instance, two ¾" sections of pipe are connected with a ¾" coupling and pulled in the Olsen Testing Machine, it requires approximately 9000 pounds per square inch before a failure occurs, and this failure is always in the pipe itself, and not in the joint. This is, of course, far beyond anything it would be required to stand under actual service.

COUPLING
Copper to Inside Thread

A copy of our catalog, fully illustrating and describing these products, together with simple instructions for connecting, will be sent upon request.

STREAMLINE Fittings are manufactured under Patents 1,770,852, 1,776,502, 1,890,998.

CALGON, INC.

Associated with Hagan Corporation,

calgon *Hall Laboratories, Inc., and The Buromin Company* calgon

Hagan Building, Pittsburgh, Pa.

Specialists in the Application of Glassy Sodium Phosphates to Industry

CALGON TREATMENT

Solves Four Major Water Works Problems

1. Controls Corrosion

Calgon maintains a thin, protective film over metals and metal oxides at pH values of 5.0 and higher, reducing the attack of oxygen to such an extent that corrosion ceases to be a serious problem and "red water" from corrosion is eliminated.

2. Prevents "Red Water"

Calgon added to well water as it is pumped prevents the precipitation of dissolved iron and so prevents "red water" from this source, whether oxidation is due to exposure to air, aeration during iron removal, or chlorination.

3. Stabilizes Water Following Lime Softening

Calgon added after the softening process effectively controls excess calcium carbonate in solution, which otherwise forms scale in water lines and hot-water heaters. Calgon stabilizes water throughout the system—at any pH value—and eliminates precipitation of calcium carbonate scale in hot-water heaters.

4. Prevents Scale Formation from Hard Water

Where water is high in bicarbonate alkalinity, the use of Calgon at the plant affords a simple, economical means of stabilizing water and eliminating precipitation of calcium carbonate scale in consumers' heater coils, tanks and hot-water lines.

Calgon Characteristics

Calgon is a complex sodium phosphate glass produced by a thermal process from food-grade phosphoric acid and soda-ash. Readily water soluble, unadjusted Calgon glass has a pH of approximately 6.0 in 1 percent solution. Impurities and moisture total less than 0.2 percent.

Calgon is as harmless as table salt; even in amounts many times greater than those employed in municipal water treatment it produces no adverse physiological effect.

Calgon Treatment

The amount of Calgon used in treatment is extremely small . . . from 1 to 5 parts per million of water. Since little or no equipment is required, the total cost is well within the budget of most water departments. Calgon Treatment is a sound, accepted process which corrects water troubles without introducing new ones. It is now being used successfully in more than 300 municipal water systems, ranging in capacity from 10,000 to 120,000,000 gallons per day.

Whether your problem is stabilization of softened water, corrosion control, "red water" from dissolved iron, or hard, high-bicarbonate water, Calgon can help you. Technical information on specific water problems and a free sample of Calgon* for laboratory test purposes will be furnished on request.

**Calgon is the registered trade-mark of Calgon, Inc., for its glassy sodium phosphate products.*

Authorized Calgon Representatives

Birmingham—Eshelman and Potter, 1116 Martin Bldg.
Boston—Ralph L. Williams, 49 Federal Street.
Buffalo—Charles A. Randorf, 321 Jackson Bldg.
Charleston, W. Va.—C. H. Turner, 811 Red Oak St.
Charlotte—Eshelman and Potter, 314 Wilder Bldg.
Chicago—Burke & Colston, 1316 Austin Bldg.
Cincinnati—L. I. Snodgrass Co., 18 East 4th Street.
Cleveland—Chas. H. Tate Co., 404 Newman Stern Bldg.
Denver—Denver Fire Clay Co., 2301 Blake Street.
Detroit—Calgon, Inc., 2512 Book Building.
El Paso—Denver Fire Clay Co., 209 Mills Bldg.
Franklin, Pa.—Alfred Watson, 315 Fourteenth Street.
Houston—Maintenance Engrg. Corp., 3611 Clinton Drive.
Kansas City, Mo.—H. O. Halden, 900 Porter Bldg.
Los Angeles—Griffin Chemical Co., 1925 East Olympic Blvd.
New York—Simler & Sengstaken, 271 Madison Avenue.
Philadelphia—Ash Engineering Co., 225 South 15th Street.
Pittsburgh—Calgon, Inc., Hagan Bldg.
St. Louis—Calgon, Inc., 1208 Continental Bldg.
St. Paul—Fuel Economy Engrg. Co., 510 New York Bldg.
Salt Lake City—Denver Fire Clay Co., 225 W. So. Temple St.
San Francisco—Griffin Chemical Co., 1000 Sixteenth Street.
Seattle—Northwest Filter Co., 122 Elliott Avenue West.
Toledo—Power Equipment Co., Oak Harbor, Ohio.

Canada

Montreal—
Dominion Flow Meter Co., Ltd., 515 New Birks Bldg.
Toronto—
Dominion Flow Meter Co., Ltd., 54 Wellington St., W.

Mexico

Mexico, D. F.—
Mackie T. Wright, Apartado 918, Artes No. 65.

THE MECHANISM OF CORROSION OF WATER PIPES

And Suggested Formulae for Corrosion Index

By THOMAS M. RIDDICK,
Consulting Engineer and Chemist, New York City

WE HAVE used lime and talked pH adjustment for corrosion control, but the question raised in the author's mind is this: Haven't we come to disregard many of the other significant factors in corrosion? The answer, based on what is to follow, is seemingly that we have.

Atmospheric rusting of steel has been squarely faced by the automotive industry, and their processes of Parkerizing, Bonderizing, etc., are now remarkably successful. It is high time that we of the water works field attempt to more closely correlate theory with practice, standard chemical analyses with specific pipe deterioration, and get away from well worn descriptive alibis such as "soft New England waters."

The suppression or retardation ("prevention" is surely a misnomer) of corrosion is more necessary today than ever before. All indications are that economic conditions will be more stringent for both municipalities and public utilities than heretofore, regardless of the outcome of the war. Both individually and collectively we must tighten our belts another notch and do as best we may with existing supplies and equipment. Household plumbing and the carrying capacity of distribution mains should be judiciously conserved.

A highly corrosive well or surface water that dezincifies yellow brass, removes the galvanizing from steel, and forms the familiar patina on copper tubing should not be delivered into the piping system without treatment simply because no inconvenience has been occasioned to date to the Water Department. If cut sections of household plumbing show relatively rank corrosion, undesirable things are also taking place within the distribution system, although it may not be evident in terms of red water or reduced carrying capacity if pipe lines have been in service less than twenty years. The water works official is the only person in a position to investigate and, if possible, reduce corrosion. Likewise, should it not be that the household plumbing investment of the property owner be given the same consideration as that of the Water Utility.

Two Prevalent Misconceptions

There are two prevalent misconceptions which seem inbred and self-perpetuating in Boards of Water Commissioners. The first is that current water rentals pay for the "Cost of Water." For certain municipalities this may be true, but more often the financial gross intake meets only current operating expenses with little allowance for proper maintenance and depreciation and no consideration is given to bonds retired out of the general tax or by assessment. The writer is familiar with two such water districts having relatively large distribution systems. The rate of $2 per 1,000 cu. ft. is about one-third the true charge if direct taxation is considered, but the true cost of $6 per 1,000 cu. ft. could not possibly be assessed directly without arousing the consumer's ire.

These facts should definitely be faced in figuring the increased cost which results from treatment for corrosion correction. For example, a certain corrosive well water with a CO_2 content of 12 ppm should be treated. The rate is $2 per M. and the required chemical dosage of lime, soda ash or sodium hydroxide is about 10, 29 and 11 ppm, respectively. If treatment was instituted, the additional cost per 1,000 cu. ft. would be 0.33, 2.7 or 2.4 cents, respectively. However, even the maximum increase (using soda ash) would be less than 1.5 per cent based on the prevailing $2 rate, or one-half of 1 per cent based on the "actual cost" of water to the consumer.

If the property owner was given his choice, i.e., "you may have a natural well water which is rather corrosive to your household plumbing at $2 per M., or a water which is as non-corrosive as is practicable to produce—providing maximum life to your household plumbing—and minimum red water for $2.03 per M.," there is hardly a question of doubt as to his selection.

Though these are the facts, either they have been poorly presented to Water Boards or else human inertia is a costly proposition.

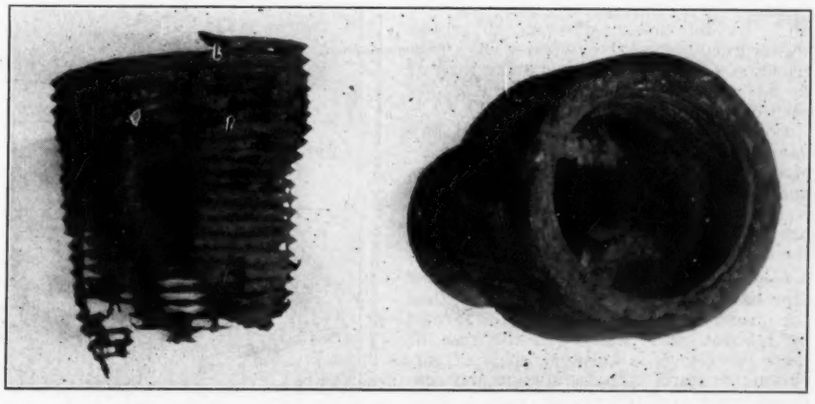
There is one other ghoul permanently stationed behind those Water Board Chairmen who offers the following argument whenever treatment is discussed—"We have *pure natural water*, and don't want any chemicals added." Thereafter the matter is closed. It seems impossible to get across the facts of the case, which are these: There never has been and never will be any "pure" natural water. All ground water contains "chemicals," principally limestone, gypsum, sodium chloride, sodium bicarbonate, and silica, and the gasses—carbon dioxide, oxygen and nitrogen. If a watershed (and all natural water comes from *some* watershed, regardless of its proximity to the well or intake) contains a large amount of gypsum and has marshy areas to contribute carbon dioxide, then a corrosive water is inevitable. If the watershed is composed mostly of limestone (with little gypsum) and few marshy areas, then the mineral content may be high and the water relatively non-corrosive. There are fewer waters in the latter class, and for some of these nature has been over-generous and difficulty may be encountered due to clogged hot water pipes.

The application of chemicals is simply an attempt to produce a "balanced water" applicable to domestic and industrial use, and suitable for conveying in metal pipe. The chemicals added are as "natural" as if nature had created them originally on the watershed.

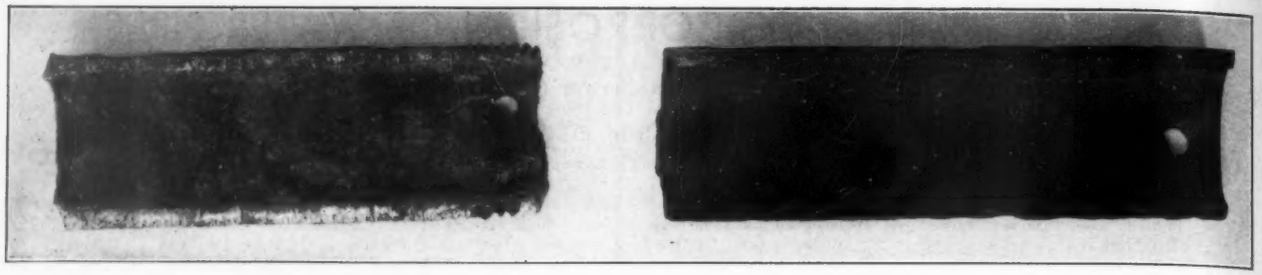
Two Stages of Pipe Life

The useful life of pipe should be divided into two distinct phases. The primary stage is that period during which pipe coatings remain intact or are gradually removed; and the secondary stage involves the direct attack of water on the pipe metal.

Section cut from 4" galvanized wrought iron distribution pipe—service 7 years; note uniform coating of red iron oxide streaked with zinc oxide.



(Left)—Section of 2" riser pipe at entrance to elevated wooden storage tank. Cause of corrosion—low pH, low alkalinity, high sulphate content and high carbon dioxide. (Right)—Corrosion due to use of dissimilar metals—brass vs. wrought iron. Pipe diameter reduced to ⅛ inch.



(Left)—Completely clogged section of cold water pipe—accumulation due to organic matter and iron in unfiltered surface supply plus iron derived from corrosion of distribution mains.

(Right)—Completely dezincified brass service line. Pipe is very brittle and failed through longitudinal split. Cinder fill was contributory cause.

If cast iron and steel pipe coatings are impervious and insoluble, and/or the water is relatively non-corrosive, the first stage may exist indefinitely. These are optimum conditions and result in the absence of "red water" and tuberculation, and pipe carrying capacity is sustained.

However, if coatings are pervious to water or soluble, and allow corrosive water to come in contact with the cast iron or steel, then the formation of creeping tubercles will tend to physically remove the remaining coating, thus exposing more pipe surface to the action of the water. Blisters (small masses of iron oxide overlying pits) form first and grow into tubercles unless the action of the water is inhibitive to the combination of oxygen with iron or steel.

Red water occurs in the second stage, but of far greater importance is the loss in carrying capacity of pipe lines. If water is pumped through transmission mains at relatively high velocity, the increase in power cost can be measured in terms of dollars. If the supply is wholly by gravity, the loss is manifest through reduced pressures on the distribution system and eventually creates a serious hazard from the standpoint of fire protection.

Normal corrosion of cast iron has never been feared from the standpoint of structural deterioration of such pipe to the extent of failure. If this was the case, superintendents and water boards would be mroe alert. Many municipalities, however, stand idly by and allow pipe to tuberculate to such an extent that 12-inch mains are reduced to the equivalent of 10 inches or less, without facing the facts.

This second stage of corrosion is one with which most water departments have to compete, though the use of cement or bituminous enamel linings today give more promise for the future. With pipe coatings removed and pipe surfaces roughened with blisters, all that can be done is to attempt to lessen the corrosivity of the water and its tendency to produce iron rust, which causes consumers' complaints, and to prevent small blisters from growing into large tubercles.

The second stage is more rapid than the first, and the accelerated rate is particularly emphasized after pipe cleaning has been necessitated. There is more than advertising copy in the paint manufacturer's slogan, "Save the surface and you save all." By this token, the time to protect the original surface is when a new distribution system is installed rather than 10 to 50 years later after the damage has been done.

Corrosion of galvanized steel and galvanized wrought iron are likewise characterized by two stages of deterioration, and the loss of carrying capacity, the stripping of threads and the occurrence of pin holes are evident remarkably soon after the zinc has been removed.

Copper tubing and yellow or red brass pipe have no protective coating other than the insoluble oxides and carbonates formed by reaction with water. In the case of these pipes there is only one stage of corrosion. It starts with installation and continues until replacement, or until a truly protective coating has been formed. Yellow brass, the most extensively (though unwisely) used of all copper bearing pipe, often requires renewal within five to fifteen years, and there are even instances of severe pitting of copper tubing (particularly class M and L) then necessitated replacement in an even shorter period.

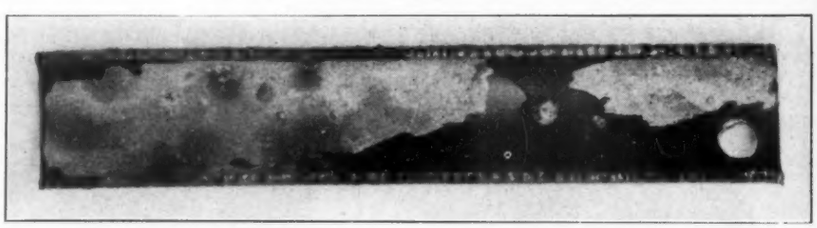
Types of Corrosion Encountered

Let us consider some of the types of corrosion normally encountered in water pipe. For want of a more descriptive term, the small nodules of red iron oxide which form on cast iron pipe will be called "blisters" and sizes above buck-shot will be classified as "tubercles." "Pits" will be considered as those areas (regardless of depth) underlying tubercles, or those exposed indentations created by removal of metal.

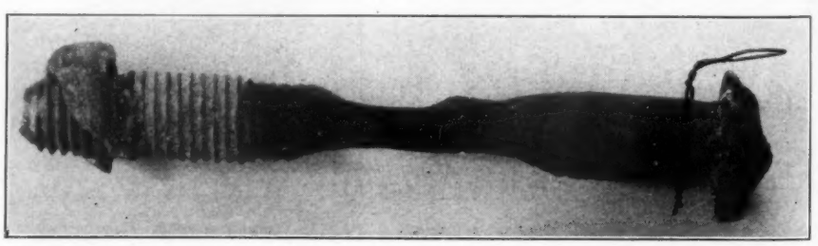
If a blister or tubercle is pried loose from a cast iron pipewall, we find that the tar or pitch coating is absent or cannot be identified readily. The volume of the tubercle is from three to ten times that of the original iron—or the volume of the "pit." The swelling action, due to formation of the oxide (hydrous oxide) has therefore been responsible not only for the formation of a protrusion which lessens pipe diameter and increases frictional resistance but it has pried away (in its formation) a sizable amount of pipe coating adjacent to the original point of attack, which was initially only microscopic in size.

Composition and Growth of Blisters

The composition of the blister is primarily red iron oxide (Fe_2O_3). On the underside, however, and on the surface of the shallow "pit" we may find a predominance of black crystalline magnetic iron oxide (Fe_3O_4). This can be identified microscopically or by lightly scraping the underside of a freshly removed tubercle and subjecting the crystals to the action of a bar magnet. It must be that the magnetic oxide of iron is the first product formed, since it lies next to the metal surface, and that the Fe_2O_3 is the final stage of oxidation. It is possible that the very



Copper tubing after 5 years' service. Failed through pitting. Note heavy formation of copper carbonate. Cause, possibly electrolysis.



Acid type corrosion of ¾" coupling bolt for Universal Pipe. Note absence of any iron oxide. Failure probably due to small amount of cinders in fill.

first stage was the lower oxide, FeO. The three stages of oxidation in their simplest expressions would be:

$2\,Fe + O_2 = 2\,FeO$ (ferrous oxide)
$6\,FeO + O_2 = 2\,Fe_3O_4$ (magnetic iron oxide)
$4\,Fe_3O_4 + O_2 = 6\,Fe_2O_3$ (ferric oxide)

If blisters were "watertight," they would cease to grow from within. Enlargement of small blisters into large tubercles is probably accomplished in three ways:

1. Growth from *without*, by deposit of iron oxide derived from the water per se, or from corrosion of the distribution system by the water en route.
2. Growth of the tubercle from *within* by the passage of water (carrying oxygen) through the amorphous red iron oxide to the pipe metal.
3. Growth of the tubercle from *within* by the passage of water (carrying oxygen) through the peripheral seal of the tubercle, to the pipe metal.

In the first stage of growth, it is probable that oxygen gains admission through the relatively thin coating of amorphous red oxide. As growth advances, more oxygen is admitted around the ever enlarging periphery of the nodule, and less through the body of the growth. The nodule is generally held to the pipe metal by the crystalline interlocking of the magnetic iron. When tubercles are removed by "prying loose," they generally remain intact, which indicates that the plane of structural weakness lies in the under zone of magnetic iron next to the metal. It is logical to presume that a thin crystalline plane offers less resistance to the passage of water than the dense mass of red iron oxide forming the body of the nodule.

What is the property of red iron oxide which holds it together in a ceramic like mass? The hydrous or anhydrous forms of the pure compound will not agglomerate and harden at normal temperatures. When tubercles are ground in a mortar and analyzed, the silica content (or what we differentiate as silica) is several per cent. Silicates are the most widely used cementing agents in both nature and industry, and it is logical to assume that this is one of the factors which is responsible (perhaps fortunately so) for tubercle formation. If water has a pronounced tendency to corrode metal, it is preferable to have it form a protective scale rather than to continuously discharge ferrous bicarbonate or iron oxide to the consumer. If silica is present in the tubercle, its source must be the water itself if no silicates have intentionally been applied to suppress corrosion.

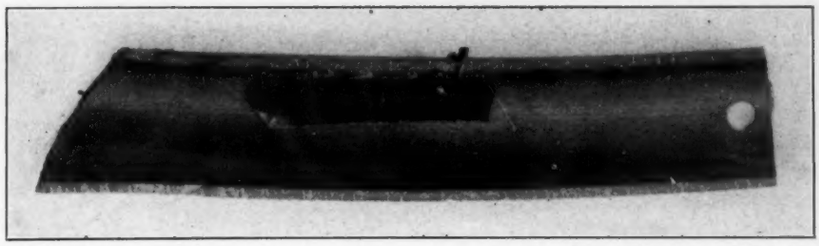
Again, It Pays to Save the Surface

If water treatment is necessary, it should begin when the distribution system is installed. Although little published research exists on the subject, it is likely that high carbon dioxide and low pH has a tendency to dissolve and penetrate pipe coatings more rapidly than neutral or alkaline waters.

Once pipe coatings are removed, water treatment may "reduce" but never "eliminate" corrosion. The manner of inhibiting the further oxidation of iron or steel seems to be:

1. To precipitate or force calcium carbonate out of solution to form a "protective film" or "protective coating" on the walls of the pipe.
2. To lessen the tendency of iron to dissolve and/or unite with the oxygen content of the water.
3. To make existing blisters, tubercles, or coatings of iron oxide more impervious and impenetrable, thereby more effectively preventing the contact of the oxygen carrying water with the pipe metal.

The writer believes that the first principle has been over-em-



Excellent example of nature's "overtreatment" of a well water. Protective scale of calcium and magnesium carbonate and sulphate formed in a hot water line. Jet black color, due to manganese. Removed from service due to clogging.

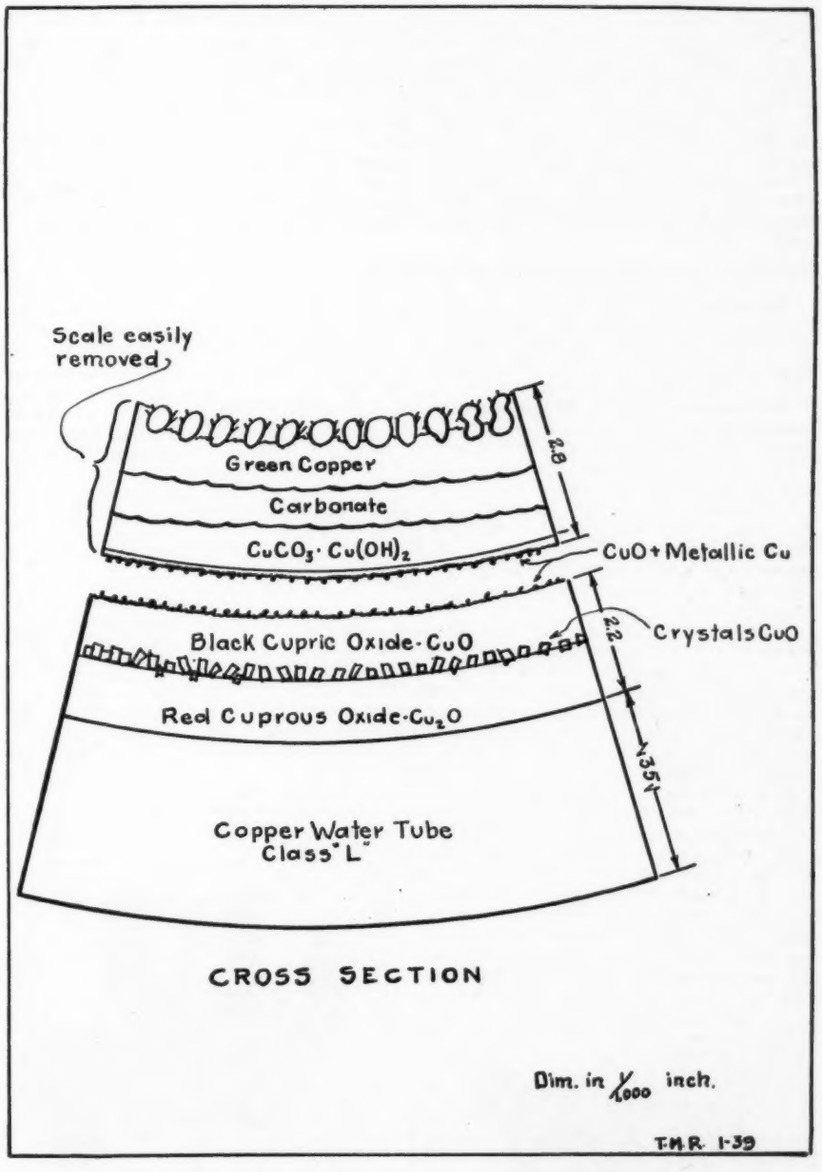
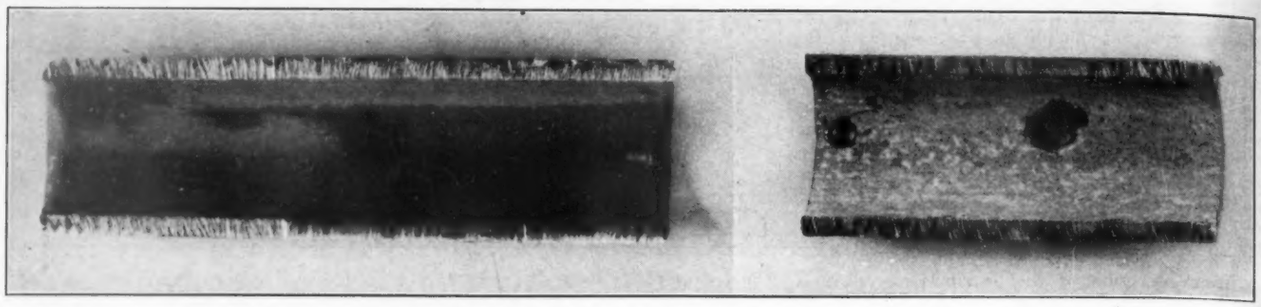


Plate 1—Sketch of a Section Cut From Copper Tubing Which Suffered Severe Corrosion

(Under the microscope this section, as sketched, revealed the mechanism and end products of the progressive corrosion as explained in the text.)



(Left)—Split section of yellow brass house plumbing completely protected by coating of iron oxide from the distribution main. (Right)—Dezincification of galvanized wrought iron.

phasized. There are certain natural non-corrosive waters which contain insufficient mineral salts, and have pH values entirely too low, to ever force calcium carbonate out of solution. Their non-corrosive properties must surely be derived from the two principles last mentioned. If alkalinity, pH and calcium content is maintained at a point to provide *adequate* "film protection" to cold water lines in winter months, then the change in temperature from between 32 and 40° F. to between 140 and 160° F. should clog a lot more hot water systems than we hear about, and consumers are never remiss in voicing such complaints to the water utility.

The More Important Functions of Treatment

The writer feels that the more important functions of treatment are to reduce the tendency of the water-borne oxygen to unite with iron, and to further cement or "waterproof" the iron oxide already present in the pipe, whether it be in the form of a surface film, blisters or tubercles.

This cementing action is quite apparent when we observe water containing less than a "trace" of iron, if any, drawn from mains coated with tubercles to a thickness greater than one inch.

Galvanized pipe, either steel or wrought iron, first exposes a zinc surface to the attacking water. Primary corrosion results in the formation of both zinc oxide and carbonate. It is likely that the oxide is first formed, which might of itself form a protective coating. Carbon dioxide, however, seems to combine readily with the oxide to form a coarse crystalline carbonate, which is removed by gradual solution as well as breaking away from the pipe walls in small pieces.

Once the protective zinc has been attacked sufficiently to allow water to reach the wrought iron or steel, the upheaval of scale is more rapid due to the bulking effect of iron oxide. Thereafter, the pipe walls become coated with blisters or scale of red iron oxide, and subsequent deterioration seems comparable to cast iron tuberculation. Steel is, as a rule, attacked more rapidly than wrought iron, and its life may be quite short after complete removal of zinc.

Zinc is more resistant to corrosion than iron or steel, else its application to pipe surfaces would be pointless. Again the emphasis should be on preservation of the original surface.

Red brass, yellow brass, and copper tubing have no protective coating other than the surface film of the metal itself. Yellow brass pipe is unreliable for most waters and should be barred from plumbing use. Gradual deterioration is through the removal of the zinc to form oxide and carbonate scales although a sizable amount of copper is also present. Failure occurs

1. At the pipe threads, particularly if these are cut deep.
2. By gradual reduction of wall thickness, and pitting to produce "pin holes."
3. By complete dezincification, which leaves the copper in a semi-crystalline state.

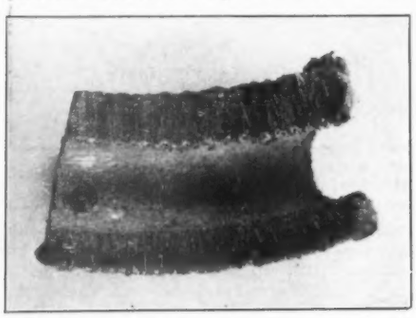
Tell-Tale Indications of Yellow Brass Deterioration

The occurrence of a "white powder" at joints of yellow brass is common, but a visual inspection of piping in service for several years will give little indication whether the powder is zinc carbonate or white lead oxide—a compound often used in "pipe dope." Microchemical analysis gives ready identification, however, and if zinc is predominant, the remaining years of useful service of the yellow brass are numbered.

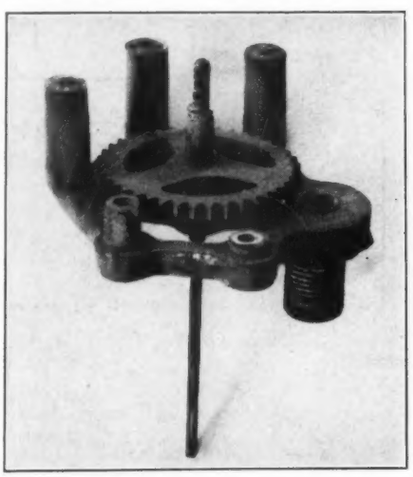
Several years ago the writer instituted treatment for an estate where yellow brass was used throughout, and many sections had "pin hole leaks," necessitating pipe replacement. Copper carbonate was present in sufficient amounts to impart a heavy green stain to laundered goods and to porcelain beneath dripping faucets. The complete neutralization of CO_2 and raising the alkalinity about 40 ppm completely inhibited the further discharge of copper carbonate, and since no leaks have subsequently occurred, it is reasonable to state that corrosion or further dezincification has been very greatly reduced.

Complete dezincification with embrittlement of pipe metal is not common. It is possible, however, and small fragments could easily be broken from one specimen examined by the writer. The plane of fracture showed no metallic copper whatsoever, and this could only be observed by cutting through the specimen with a saw.

Red brass, containing 15 per cent zinc, seems more resistant to corrosion even than copper tubing, or expressed conversely, some waters very low in mineral solids and high in carbon dioxide attack copper tubing readily, but red brass either slowly or not at all. For the less corrosive waters, little comparison can be drawn since the life of both is, and should be, for a much longer period than we have on record today.



Impervious green coating on lead service pipe.



Corrosion of meter parts. Brass frame, shaft and gear coated with iron oxide.

Meter disc chamber badly pitted and encrusted with copper carbonate.

Some Observations of Corrosion of Copper Tubing

A section of badly corroded type L copper tubing, which had pitted-through or "pinholed" in spots, is sketched to scale in Plate 1. The surface scale, which was easily removed in long cylindrical rolls, was green copper carbonate. This was bound to the scale adhering to the pipe wall by black cupric oxide, which was distinctly crystalline in structure. The method of attachment was therefore quite parallel to that of tubercles on cast iron pipe walls. Beneath the cupric oxide was a layer of red cuprous oxide Cu_2O, which apparently was being formed from the metal of the tubing. This progressive oxidation somewhat substantiates the conclusion that the first oxide formed in tuberculation of cast iron pipe was ferrous oxide FeO, which is not so readily identified as the red cuprous oxide, Cu_2O.

The order of oxide formation, expressed in simplest terms, is as follows:

$4\,Cu + O_2 = 2\,Cu_2O$ (cuprous oxide)
$2\,Cu_2O + O_2 = 4\,CuO$ (cupric oxide)
$2\,CuO + H_2CO_3 = CuCO_3 \cdot Cu(OH)_2$ (cupric carbonate)

If a standard mineral analysis had been made of the *removable* scale only, the stages of oxidation or carbonation would not have been manifest. This suggests the necessity of employing microchemical methods, as was done in this instance, and the need of a more fundamental study of the progressive stages of corrosion.

In the absence of carbon dioxide, it is probable that only cuprous and/or cupric oxide would be formed, which serve far better as a protective film than the more porous cupric carbonate.

This conclusion points strongly to the presence of carbon dioxide as a potent factor in corrosion, but it does *not* explain why *some* supplies containing high amounts of CO_2 do not actively attack copper tubing.

Practical Observations vs Theory

The writer has long felt that the approach to corrosion in the water works field has followed too much the same line of reasoning. And, axioms (some formulated years ago for specific supplies) have too generally been accepted and applied. There are no two waters the same, and it is only by viewing corrosion of many supplies that we may form a concept of the fundamental underlying principles.

It is often true that practice precedes theory, and with this in mind, the writer has tried to disregard some of our accepted tenets and evolve a rational approach from the standpoint of *evidence* rather than theoretical reasongin and what are accepted as chemical laws.

If we have a practical knowledge of many supplies, natural or treated, they may be classified as "non-corrosive," "corrosive" and "very corrosive," based only on (1) frequency of hydrant flushing on dead ends and time required for hydrants to flush "clean," (2) occurrence of red water on the distribution system, (3) life of galvanized steel, galvanized wrought iron, copper, red and yellow brass pipe, and hot water boilers, (4) tuberculation of mains, (5) loss of pipe carrying capacity, (6) stains on porcelain, (7) occurrence of brown or green stains on laundered materials, (8) dezincification of galvanized steel or wrought iron, yellow brass pipe, etc., etc.

If the chemical analyses for such classified waters are compared, we find little if any correlation for any *one* constituent and *this particularly applies to pH*. But considering the mineral and gaseous components, a general pattern seems to be evolved.

If we occasionally find natural, untreated, well and surface supplies which are relatively non-corrosive, should we not consider them somewhat as a criterion when we begin to alter the characteristics of water by the addition of lime, soda ash, caustic soda, silicate, and the aluminum and iron coagulants?

I do not infer that nature cannot be improved upon. It can, as is evidenced by the applications of vitamins to aid plant growth, but until we have at least *equaled* natural processes, let us not try to improve upon them.

The physical and chemical tests which should be employed in the evaluation of any water are: Turbidity, Color, Odor, Carbon Dioxide, Alkalinity, pH, Hardness, Iron, Manganese, the Nitrogen Determinations, Chlorides, Temperature, Dissolved Oxygen, Silica, and Solids.

The complete mineral analysis is far too time consuming to ever be used from a practical standpoint, unless a lot more time and money is expended than heretofore.

To judge the corrosive qualities of a water *per se* (not the *effects* of corrosion) the writer believes that the following tell most of the story: Carbon Dioxide, Alkalinity, Hardness, Silica, Dissolved Oxygen, Chlorides and Nitrates.

The two constituents last classified are generally present in such low amounts (in Atlantic coastal supplies at least) as to render their inclusion rather dubious. Oxygen can only be determined accurately in the field and is not a "routine" test. Silica should definitely be included in routine examinations, although the method of analysis is of doubtful accuracy.

Three Empirical Formulae Evolved

The writer has evolved three purely empirical formulate to numerically express the corrosive tendencies of water, based on correlation of Standard Methods tests with the physical manifestations of corrosion previously listed.

They definitely take hydrogen ion concentration (pH) into consideration by the inclusion of Carbon Dioxide and Alkalinity, and I believe evaluate their true importance more accurately than does the pH test.

Formula 1 is most applicable to routine analyses as performed by most commercial and state laboratories, and is as follows (analytical values are expressed in ppm.):

$$(1)\ \text{Corrosion Index} = [CO_2 + \tfrac{1}{2}\,(\text{Har.} - \text{Alk.}) + Cl_2 + 2N]\,\frac{75}{\text{Alk.}}$$

It gives numerical values ranging from about 5 to 150, which are evaluated by the writer as follows:

0-5	Extremely non-corrosive
6-25	Non-corrosive
26-50	Moderately corrosive
51-75	Corrosive
76-100	Very corrosive
101+.	Extremely corrosive.

This formula is generally applicable to waters on the eastern seaboard. It may apply or may be totally inapplicable to those of the west or midwest. It holds primarily for natural waters but seems to give good interpretations for treated supplies.

There are two other factors of prime importance which have been omitted since many laboratories do not make these tests as routine—they are Silica and Dissolved Oxygen.

When the silica test is made, the following correction may be applied:

$$(2)\ \text{Corrosion Index} = \text{CI}\ (1) \times \frac{10}{SiO_2}$$

If dissolved oxygen is also included, the formula is:

$$(3)\ \text{Corrosion Index} = \text{CI}\ (1) \times \frac{10}{SiO_2} \times \frac{DO + 2}{\text{Sat. DO}}$$

$$\text{or} = \text{CI}\ (2) \times \frac{DO + 2}{\text{Sat. DO}}$$

It is observed that the formulas particularly stress total alkalinity and non-carbonate hardness. The writer is firmly convinced that the latter, which is often magnesium sulphate, is a potent factor in corrosion.

Several natural "non-corrosive" waters are listed in Table 1.

pH values are below those normally carried in alkali treated waters and range from 6.3 to 7.8 Corrosion indices are uniformly low, however, except for the well water having a value of 62. The inhibiting factor in this case is naturally the low dissolved oxygen. Obviously formula 3 would have been more applicable. The only common characteristic of the group is *low non-carbonate hardness.* Although these natural waters are listed as non-corrosive, there is no doubt but that complete neutralization of carbon dioxide and the maintenance of several parts per million of carbonate alkalinity would have rendered them still less aggressive.

Several extremely corrosive waters are shown in Table 2.

Again the only common characteristic is high sulphate content, though the effect of low alkalinity seems pronounced. In the reservoir water and the shallow well supply last listed, the writer is convinced that sufficient alkalinity could not be supplied by lime without excessive pH, and in these instances soda ash or caustic soda would be the preferable chemical to apply.

It has been known for some time that waters low in carbon dioxide and alkalinity could not be given sufficient lime to form a protective coating, but the writer feels that there is some further principle involved which may be roughly expressed as a hardness-alkalinity or carbonate-sulphate ratio.

An example of the application of lime or soda ash to alum treated water, either before or after secondary aeration, is shown in Table 3.

Here is indicated the advisability of adding lime or soda ash *before* rather than after secondary aeration. The Index is probably somewhat exaggerated, though plant operation showed that corrosion was reduced by substituting soda ash for lime in post

aeration treatment, and a split dosage of pre lime and post soda ash has been instituted.

Based on correlation of chemical analyses with pipe deterioration, the following factors tend to reduce corrosion:

(1) Low non-carbonate hardness, or low sulfate content.
(2) High alkalinity.
(3) High silica content.
(4) Low carbon dioxide.
(5) Low oxygen concentration.
(6) Low temperature.

Those tending to accelerate corrosion are the converse of the above.

The writer wishes to emphasize that the empirical corrosion indices listed were prepared on a cut and try basis over a period of years and are naturally subject to discrepancies and to change. They constitute a "rule of thumb" method for evaluating the corrosive qualities of a water, based on normal chemical analyses, and admittedly there is no phase of water treatment that can be competently handled on such a basis.

The formulae are presented with the hope they may elicit further practical research, and that a sufficient number of operators, chemists and superintendents will apply them, to either substantiate, improve, or entirely discredit the Indices.

The writer will be glad to receive reports from water works personnel as to their applicability to specific supplies.

TABLE 1—RELATIVELY NON-CORROSIVE WATERS

Results in parts per million

Source	River	Spring	Deep Well	Deep Well	Deep Well	Spring
Carbon Dioxide	1	1.5	18	16	8	0
Alk. (Bicarb.)	100	66	30	92	130	28
Hardness	104	76	34	88	131	28
Chlorides	4	4	5	5	9	3
Nitrates	1	0.4	0	0	1	0
pH	7.9	7.3	6.3	6.8	7.4	7.8
Silica	..	..	7	..	..	..
Dissolved Oxygen	..	..	2.4	..	..	..
Corrosion Index*	7	13	62	17	11	8

*Computed with formula (1).

TABLE 2—VERY CORROSIVE WATERS

Results in parts per million

Source	Shallow Well	Shallow Well	Reservoir	Deep Well	Deep Well	Shallow Well
Carbon Dioxide	11	18	3	14	18	26
Alk. (Bicarb.)	5	9	9	18	34	8
Hardness	60	22	20	34	60	46
Chlorides	20	5	2	3	5	13
Nitrates	11	1	0	0.5	1	1
pH	5.5	5.8	6.6	6.1	6.6	5.5
Silica	..	2	5	6	..	..
Corrosion Ind.*	1050	267	92	108	82	560

*Computed with formula (1).

TABLE 3—EXAMPLE OF EXTREME VARIATION IN CORROSION INDICES DUE TO POINT OF APPLICATION OF ALKALI

Results in ppm.

	Raw W. After Aeration	Filtered Water	Filt. W. After Sec. Aer.	Finished Water—Lime Before Sec. Aer.	Finished Water—Lime After Sec. Aer.	Finished Water—Soda Ash Before Sec. Aer.	Finished Water—Soda Ash After Sec. Aer.
Chem. Dosage, ppm	..	..	..	13	4	36	10
CO_2	2	15	4	0	0	0	0
Alk. (Bicarb.)	38	38	38	56	43	38	38
Hardness	18	3	3	21	8	37	12
Chlorides	3	3	3	3	3	3	3
Nitrates	1	1	1	1	1	1	1
D.O.	Sat.	Sat.	Sat.	Sat.	Sat.	Sat.	Sat.
pH	6.9	5.6	6.0	7.9	7.9	7.9	7.9
Corrosion Ind.*	71	940	660	80	210	11	110

*Computed with formula (1).

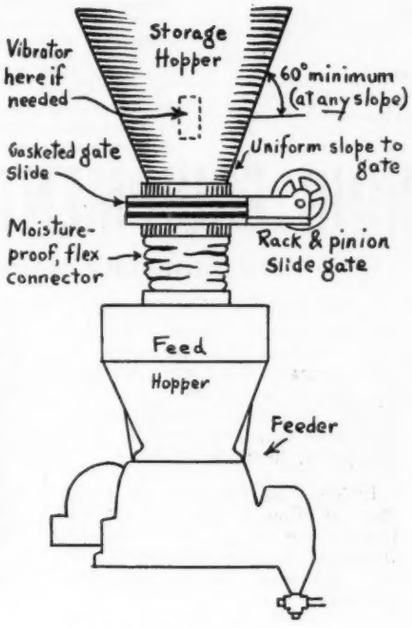
DRY FEEDERS

Some Notes on Design, Maintenance and Operation

By F. J. LAMMERS

International Filter Co., Chicago

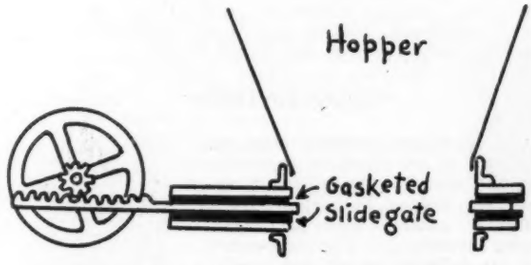
PROPER maintenance of chemical feeders has been greatly simplified by constant improvement in design and manufacture—but a few comments on application and operation may be helpful nonetheless, especially in handling a problem of unusual type of service.



Hopper Attachment

Intermittent operation may cause chemical to cake, scale or lump in the feeder mechanism, due to absorption of excess moisture from the air. Especially is this the case with lime, alum and sodium aluminate. If the usage is widely intermittent, it is best to run all chemical out of the feed mechanism before shutting it down, and a positive acting shut-off gate between large supply hoppers and the feeder proper are important for this purpose.

When periods of inoperation, or those of exceptionally low feeds, do not extend beyond a few days at a time, this difficulty can often be remedied by placing an ordinary electric light bulb in the most effective position to heat the chemical immediately in and above the feed mechanism. This will usually eliminate sufficient moisture to prevent severe lumps or scale. In feeders of the revolving table type, the bulb should be placed under the table, and as near as permissible to the adjustable deflecting knives; roller or shutter type of feeders should have the bulb close under the feed element; with screw, vibrating or gravimetric type feeders, the feed channel may be too long for adequate heating by a single bulb, and a small resistance element may be preferable. In the case of powdered carbon, however, the use of exposed heating elements is to be avoided, because carbon dust is flammable Both storage and feed hoppers should be made as tight as possible with gasketed covers, and any flexible connections between these hoppers should be of fairly moisture-proof material, or suitably painted fabric, to seal them.



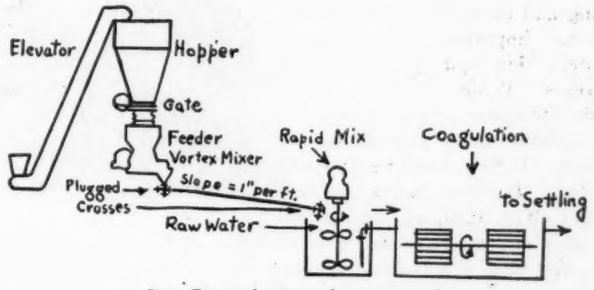
Rack & Pinion, dustproof Slide Gate

Arching in either the storage or the feeder hopper is largely a matter of original design. The hopper slope preferably should be at least 60 degrees from the horizontal. This applies to the corner joint as well as the flat of square hoppers, since arching often starts because this slope at the corner is insufficient. However, arching can be reduced if hopper covers are filleted, or slopes steepened. To hoppers with flexible walls alternating current vibrators may be attached to keep the chemical moving down the sloping walls **(see sketch.)**

Hoppers should always be equipped with screens, and these kept in place, to prevent entry of oversize material. Chemical sacks should not be opened over the hopper, as this invites the entry of troublesome string or bits of sacking which may foul the feed mechanism.

Hopper gates should work easily to permit convenient shutoff of chemical; for this purpose, sliding gates are best when equipped with rack and pinion drive, so that destructive hammering is unnecessary for opening and closing them. Hopper gates of the rotary type and so-called "bin-valves" are available as refinements for this purpose. Where there is likelihood of frequent shut-downs such gates are especially worthy of consideration.

After measurement, most dry feeders discharge chemical by gravity into a stream of water, usually in a vortex funnel or mixing chamber. At this point the amount of flow, and especially the velocity, must be sufficient to wet and sweep away the maximum chemical. A tangential water inlet is preferable, to create a swirl and vortex for maximum wetting; if velocity is insufficient for complete removal of all chemical, such may be increased



Dry Feed Installation Layout

by reducing the size or altering the shape of the inlet orifice. The water flow should not flood and close the vortex, or chemical wetting will be impaired.

The pipe lines carrying the wetted chemical to point of application should pitch at least 1 inch per foot and should have either large radius bends or, preferably, plugged crosses at each 90 degree turn, so that the lines may be readily rodded out. The discharge end should preferably *not* be submerged. Or, if submerged, the line should be vented to prevent backing up of water and to release entrained air which might otherwise produce an air lock. Also it is possible that such entrained air may be occluded by the floc, causing it to have a tendency to float (see sketch).

Vortex funnels and ejectors mainly provide mechanical removal of the measured chemical, and may not dissolve any great part of it. Subsequent agitation in a dissolving chamber should be provided for true solution, otherwise undissolved chemical may settle to the bottom of the mixing basin and be wasted. An initial, violent, short mixing of the chemical with the full flow of liquid being treated, ahead of slow coagulating mixers, will assure solution and distribution of all chemical.

INFILCO INC.

(Formerly International Filter Co.)

Water Conditioning, Sewage Treatment, Hydraulic Control and Chemical Feed Equipment

325 W. 25TH PLACE, CHICAGO, ILL.

PRODUCTS

Aerators—MultiCone, forced draft, coke tray, cascade and spray
Boiler Water Purification Plants
Carbon Purifiers—Taste, odor and color removal plants
Chemical Feeders—Dry and solution types, combination mixers and feeders
Color Removal Plants
Controllers—Chemical feed, rate of flow, liquid level, hydraulic valve
Filters—Concrete and wood gravity, pressure, and disk type water filters; also oil removal, swimming pool, etc.
Filter Plant Equipment—Controls, gauges, indicators, recorders, operating tables, transfer switches, coagulators, etc.
Fluorine Removal Plants
Gauges—Rate of flow, liquid level, etc.
Iron Removal Plants
Lime Feeders and Slakers
Proportioners—Acid and chemical feed
Sewage Treatment Equipment—Activators, Accelo-Filters, coagulators, clarifiers, dosing siphons, rotary distributors, samplers
Silica Gels
Softening Plants—Lime-soda, Hot-flow, Accelator, Zeolite.
Steam and Gas Purifiers
Sterilizing Equipment
Swimming Pool Equipment—Filters, cleaners, fittings, etc.
Taste and Odor Removal Plants
Venturi Tubes
Water Filters and Filter Plant Equipment
Water Softening Plants of all types
Zeolites and Zeolite Water Softeners

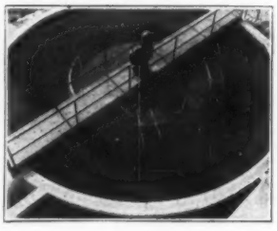
WATER CONDITIONING EQUIPMENT

INFILCO SERVICES

INFILCO has specialized in the design and manufacture of all kinds of water conditioning equipment—from aerators to underdrains—for over forty years.

The consulting engineer or his client can specify "Infilco" throughout the water treating plant knowing that such equipment has the benefit of Infilco's vast experience in supplying thousands of installations. Specifying one brand of equipment throughout gives the added assurance of undivided responsibility and coordinated results. The services of Infilco's staff of competent engineers and their complete laboratory facilities, ready to cooperate in making recommendations and reports, are at the disposal of the consulting engineer or his client.

ACCELATOR SOFTENERS, CLARIFIERS AND STABILIZERS

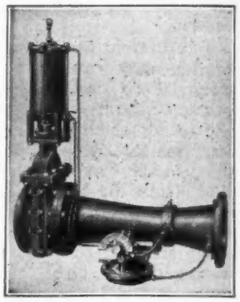


The Accelator for water softening and clarifying is one of the most important water treatment developments in recent years. While retaining all of the advantages found in the conventional lime or lime-soda processes, it offers many new advantages. Treating, mixing, reaction and clarification, all are carried out in an incredibly small space. Treating chemicals are applied in a new way. Reactions occur under new conditions. Size is but a fraction of that for old type plants where design was based upon holding time requirements for chemical and physical reactions and for sedimentation.

ZEOLITES AND ZEOLITE SOFTENERS

Infilco Zeolite Softeners are of either pressure or gravity type, and are built in sizes to meet any capacity requirement. Controls are furnished for either manual, semi-automatic or full automatic operation as desired. A variety of Infilco Zeolites are available, and the selection of type to be used will depend upon the characteristics of the water to be softened and upon requirements. All Infilco Zeolites are capable of quick regeneration, considerable overload capacity and operation at high rates of flow.

CONTROLLERS AND GAUGES



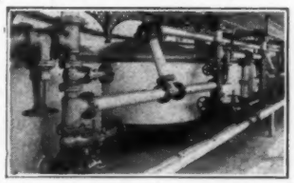
Infilco Rate of Flow Controllers, for automatically maintaining uniform rates of flow, are noted for their accuracy, low loss of head, reset and rate setter features. Infilco Water Level Controllers operate hydraulically controlled valves to maintain proper liquid levels.

Infilco Indicating and Recording Rate of Flow, Loss of Head and Liquid Level Gauges and Illuminated Indicators provide visual indication and permanent records of plant operation.

PRESSURE AND GRAVITY FILTERS

Clean, clear water, essential for municipal supply, is assured by Infilco pressure or gravity type filter plants, in capacities from a hundred gallons per day up.

The design of every Infilco filter plant is based upon sound engineering principles, backed by over four decades of experience in equipping many hundred municipal water works, and building tens of thousands of industrial filters.



RECARBONATORS

Infilco Recarbonators are available for the stabilization or recarbonation of industrial liquids, trade wastes and lime-softened water. Infilco equipment provides for the complete process of producing, cooling, scrubbing, compressing, drying and applying carbon dioxide gas to the liquid.

COAGULATORS

Infilco Coagulators promote economy and efficiency in the chemical treatment of water and sewage. The applied chemicals are fully utilized by bringing them into intimate contact with the liquid undergoing treatment. The suspended particles are collected rapidly and quickly aggregate into masses having very high subsiding values.

TRANSFER SWITCHES, OPERATING TABLES ROBOTROLS AND SAMPLING TABLES

Infilco Transfer Switches provide finger-tip control of hydraulically operated mechanisms. They meet every requirement of 4-way plugs or piston cocks without their inherent disadvantages. Extreme compactness is obtained by grouping all four separate valves in one body, along with pressure and waste passages.

Infilco Operating Tables offer both utility and a pleasing appearance. They provide centralized and simplified control for a number of hydraulically operated valves, and at the same time furnish an attractive mounting for the control levers, indicators and gauges.

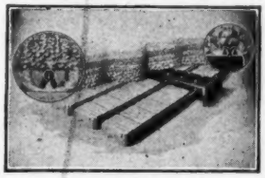
The Robotrol is a robot filter or softener operator. It backwashes (or regenerates) and returns the unit to service—automatically, efficiently and without supervision.

Sampling tables furnish a visual check on the condition of raw, settled and filtered water.

HYDRODARCO PURIFIERS

Hydrodarco is the activated carbon made expressly for water purification. Hydrodarco Purifiers, employing beds of granular Hydrodarco, automatically remove tastes, odors, chlorine, iron, organic color, etc. They are furnished in capacities from a few gallons per hour to millions of gallons per day.

INFILCO FILTER UNDERDRAINS



Wagner Filter Underdrains provide a primary distributing system of a manifold and laterals on wide centers, with distributing orifices along their undersides; and a secondary system of Wagner precast blocks fitting between the laterals. The system fills every requirement for perfect wash water distribution. With manifold and laterals of Transite (an asbestos and Portland cement product) this underdrain is practically everlasting.

FLUOREX PURIFIERS

Fluorex is a specially prepared, highly porous and reactive tricalcium phosphate for removing fluorine from water. Fluorex Purifiers, with their improved method of regeneration which prolongs the active life of the adsorbant and makes possible the use of ordinary materials and construction, offer the ideal means of removing fluorine.

AERATORS

To permit selection of the proper type of aerator to meet conditions of head and space available, character and quantity of water to be handled, and the results desired—Infilco offers its MultiCone, forced draft, coke tray, floating cone, adjustable cone and cascade aerators.

CHEMICAL FEEDERS AND PROPORTIONERS

Infilco Chemical Feeders—dry or solution—provide means for volumetrically or gravimetrically measuring and feeding chemicals in any form: liquid, powdered, granulated or lump. Capacities are from a fraction of a pound to hundreds of pounds per hour.

Infilco Continuous Lime Feeders and Slakers combine in one continuous, automatic process, the consecutive operations of feeding and slaking crushed or pebble quicklime, followed by the preparation and delivery of a suitable milk of lime mixture.

Infilco Proportioners maintain predetermined ratios between liquid or solid flows, or automatically vary the ratio of one flow with respect to another, by electric, hydraulic or mechanical means.

SEWAGE TREATING EQUIPMENT

INFILCO manufactures equipment for all sewage treating processes—chemical, biological and mechanical. In offering many products for application in these various processes, Infilco also offers the user the advantage of centralized responsibility, which is important in assuring continued satisfactory equipment operation.

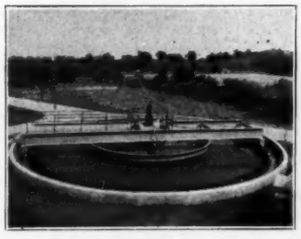
For making recommendations and reports to the consulting engineer and his client, Infilco extends its laboratory facilities and the service of its staff of engineers. It is of course not intended that this service shall conflict with the work of the engineer; rather, it is meant to be in cooperation with this work.

ACCELO-FILTER SYSTEMS

The Accelo-Filter system provides a new and improved method for treating sewage and organic wastes by constant, *direct* recirculation through the trickling filter. This results in repeated inoculation with freshly aerated material and provides effective reduction of the organic content of the biological filter at a considerably higher dosage rate.

Aero-Spray Nozzles on a rotary distributor (above) provide a fan-shaped variable spray which assures optimum coverage and maximum aeration in the application of screened, settled sewage to trickling filters. All parts of these improved nozzles are bronze to assure long life.

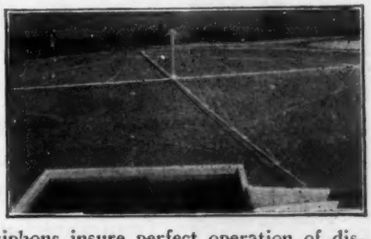
CLARIFIERS



Infilco Types WS and PD Clarifiers obtain a perfect balance of the conditions necessary for efficient operation of a sewage concentrator. These Clarifiers are designed with curved rotating scraper blades that gently concentrate and remove settled material with practically no disturbance of the liquid. Accordingly, retention periods may be selected to avoid both septic action and excessive surface scum formation.

The two different sizes of Infilco Clarifiers assure effective removal of solids from the sedimentation tank whether it be small or large. The WS Clarifier with central motor reducer drive is supplied for tank diameters up to 40 feet. For diameters larger than 40 feet, there is the PD Clarifier, driven by a horizontal motorized reducer through a pinion which meshes with a stationary rack at the tank periphery.

ROTARY DISTRIBUTORS AND DOSING SIPHONS

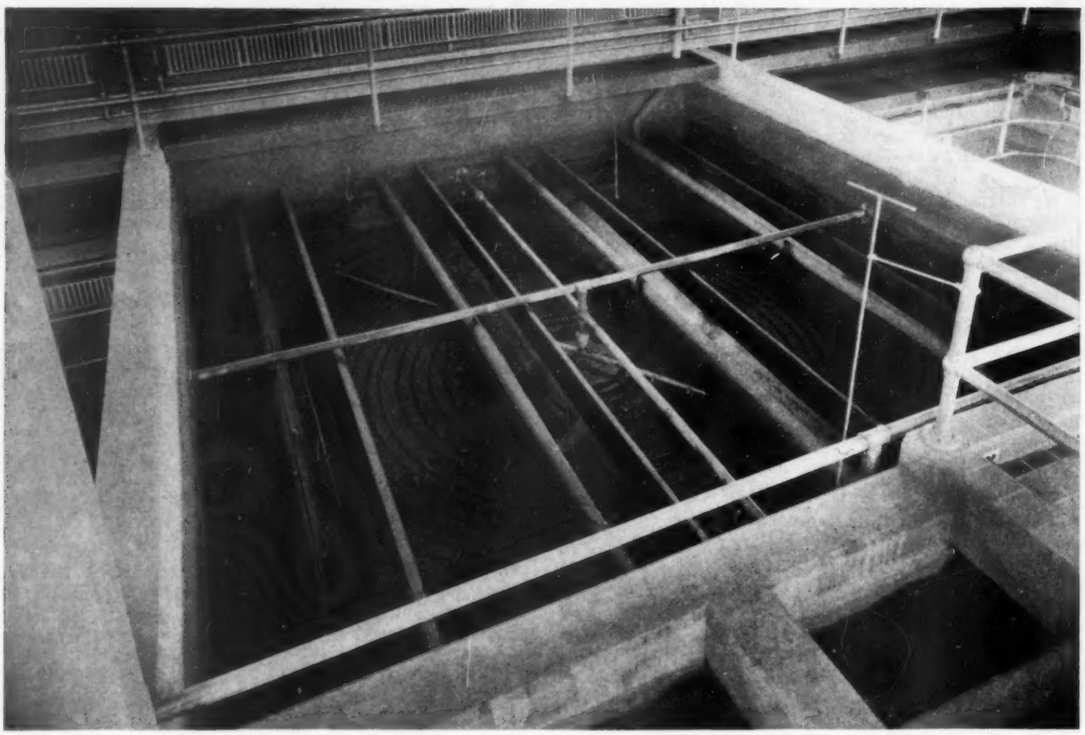


Only Infilco Rotary Distributors offer so many important refinements such as full-opening arm end gates, mercury seal with protective seal ring, and corrosion-resistant nickel iron castings, along with low operating head requirements and uniformity of distribution. Infilco dosing siphons insure perfect operation of distribution mechanism at all flow rates.

STUART-BRUMLEY CORP.

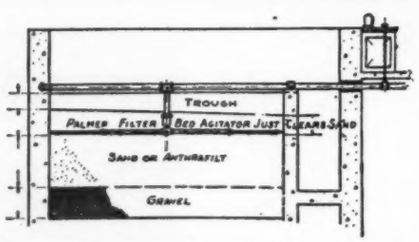
516 N. Charles St. **BALTIMORE, MD.**

PALMER FILTER BED AGITATORS



Advantages

- Long filter runs.
- Less wash water required—averaging 40 per cent reduction.
- Complete elimination of mud balls.
- Reduction of chlorine demand in filtered water—because of removal of organic matter in the filter sand.
- No more cracking or shrinking of the beds.
- Sand is as clean as new sand after about three weeks operation of the agitators.
- Better tasting water.



Operates by water at city pressure. High velocity, low volume jet action completely scours the expanded filter medium. Low cost.

Installations

Cities

Hundreds of municipalities have Palmer Filter Bed Agitators.

Industrial Companies, such as

Anheuser Busch, Inc.
E. I. du Pont de Nemours and Co.—8 plants.
General Electric Company
Hammermill Paper Co.
New Bedford Rayon Co.
American Enka Co.
Gulf States Utilities Co.
Rayonier, Inc.—3 plants.

CORROSION RESISTING PAINTS – –FILTER SAND
FILTER ALUMS – POWDERED ACTIVATED CARBON – BLEACHING CLAY

Dustless Blackalum

A powerful deodorizing and decolorizing coagulant. Contains powdered activated carbon. Prevents fermentation of sludge in basins. Fast Floccing over a wide pH range. Particularly effective for summer coagulation. Removes tastes from water supplies.

Standard Activated Alum

An economical, high alumina content coagulant. Compounded for use when dealing with water which is difficult to handle. One of America's largest selling coagulants, providing maximum coagulation economy with greatest efficiency.

FILTER WASHING

Some Observations on and Results with Methods Old and New

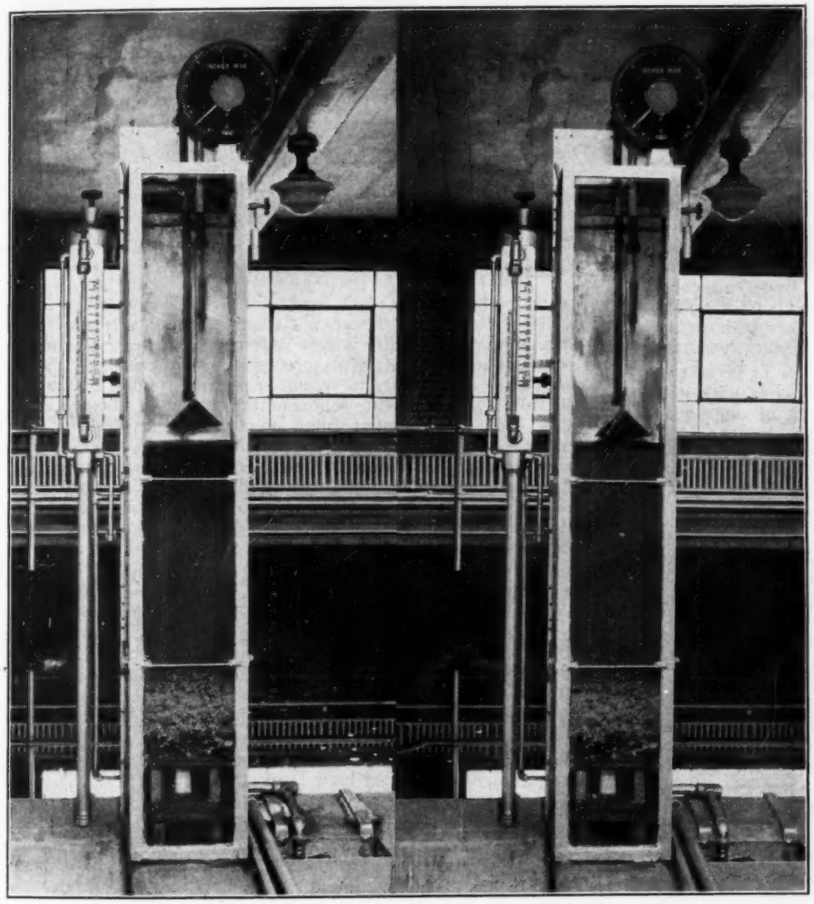
By H. J. KRUM, Supt. of Filtration and I. M. GLACE, Consulting Sanitary Engineer
Allentown, Pa., and Harrisburg, Pa.

THE authors of this paper, although having no official connections, have nevertheless cooperated for years on the solution of the many difficulties incident to the proper maintenance of public water supplies and the collection and disposal of sewage, including certain research and operating problems. The care of filters, naturally, has been one of the matters considered.

This association has been unusually beneficial to both authors and the more effective, it is felt, because one author (Krum) has had available a large and well equipped laboratory for chemical and bacteriological studies and, as chief operator of a ten million gallon rapid sand filter plant as well as several smaller swimming pool filters, has been able to install for experimental purposes many devices of varying kinds, and to put into practice a number of improved operating procedures.

Although the authors confess to differences of opinion on some of the practices of the profession, they find themselves in complete agreement on the desirability of better facilities for the cleansing of the media of filter units, and on the efficiency of the socalled surface-wash.

The data and conclusions presented herein represent a consolidation of ideas and opinions based on detailed research at one plant and on general observations at plants over a wide area.



The Allentown Experimental Filter.

Fig. 1 (*left*) *shows the layer of coated top sand after many repeated washings at high rate bottom wash alone.*

Fig. 2 (*right*) *reveals the result of sand scour secured by surface-jet wash for only a short period.*

The hanging cone is the sand bed expansion indicator developed at Allentown for indicating correct washing rates throughout the year.

Past Practices

For the sake of clarifying this discussion, and in an attempt to indicate briefly the struggle of the profession to solve this knotty problem of filter operation, the historical outline which follows is cited to show approximately the time periods in which certain designs and practices have been popular in the water works field:

—Prior to 1910—

In circular tub filters; with false bottoms, pipe laterals, a variety of types of strainer heads and, commonly, revolving fixed rakes, with "low" wash water rates of 8" to 12" rise per minute.

1910 — 1920

In rectangular concrete units; with slightly increased wash water rates, and frequently air wash as an auxiliary.

1920 — 1930

As in 1910-1920, but with "moderate" rates of wash up to about 30" rise, and with perforated lateral pipes and deeper gravel beds for better distribution.

1930 — 1940

As in 1910-1920, but with "high" rates of wash up to 48" rise per minute, a variety of filter bottoms, many of a nonmetallic character, and frequently false bottoms to replace manifolds and laterals.

Surface wash was introduced as an auxiliary to the bottom wash, with either fixed or revolving piping at the surface of the medium for such purpose. The introduction of porous plate filter bottoms, eliminating the gravel bed.

Seemingly most of the difficulties in filter washing began with the advent of the rectangular concrete box filter. This period coincided with the abandonment of the circular wooden-tub type filter and mechanical rakes.

The time periods indicated are, perforce, only approximations and considerable overlapping naturally occurs in any such classifications. As for instance, perforated pipe laterals were used as early as 1905, at the Harrisburg, Pa., works.

Mention should be made of the use of slat-bottomed units which, generally, have never been accepted by the profession because they seem to violate one of the basic principles of design; that is, the production of a uniform head at the base of the strainers, or other openings through restricted orifices.

Mention might be made, also, of the use in a number of plants of fine mesh screens, installed between the top of the gravel layer and the sand bed to prevent "upsetting" of the gravel; a condition which, it is not generally recognized, exists to some extent in practically all units not in some way protected against disturbance. This point in the filters—the junction of the sand and gravel—might well be classed as the "danger line," since a serious upset at this junction of the two media results finally in the failure of the bed to perform its functions and, ultimately, in the necessity for a complete and expensive overhauling of the affected unit. The seriousness of this problem brought forth the development of the porous-plate false bottom, a very promising improvement in design.

In addition to the listed methods of construction, an enormous amount of time and effort has been given to a study of the sizing and specific gravity of the filtering media, resulting, from a design standpoint, in the use of anthrafilt in many filters, and the use of coarser sands of a larger effective size.

All of this — revolving rakes, air wash,

false bottoms, screens as gravel retainers, "high" rates, and what not, even when combined with greatly improved mixing and coagulation of chemicals—has not resulted in the design or use of any one "best" procedure, or in the prevention of mud-balls, hard spots, and the necessity for the frequent expesive overhauling of the units; nor has it provided operators with means for maintaining a really *clean* filtering medium.

It is admitted that in some of the more carefully designed and better operated plants these interferences in filtration have been held to a minimum but so far as the water works field generally is concerned, the results are stated above.

High Wash Rates Disappointing

Of these various features of design, the so-called "high" wash rate seems to have been the greatest disappointment and the most misleading. A rise of as much as 48" per minute is exceptional but when this is expressed, as it might well be, as 4 feet per minute, the actual low velocity of such a flow can be more readily recognized. Although the actual velocities through the interstices of the expanded sand may be 2 to 3 times this stated velocity, but little sand scrubbing effect results.

The Surface Wash

Various forms of surface wash have been developed in the last half dozen years (not considering the old revolving rake in this classification) with almost universal improvement in operation.[1, 2] The development of the relatively inexpensive and easily installed Palmer Filter Bed Agitator has speeded up the trend towards such a form of auxiliary wash since it was introduced to the field in 1939, and first described by the inventor, a filter operator, in this magazine.[3]

The success of these various forms of surface wash is the result of the relatively high velocities of the jets issuing from the distributor arms, which velocities commonly reach from 50′ to 100′ per second, or 1,000 times that of the socalled "high rate" bottom wash. The tremendous scouring action of these fire stream velocities is at once apparent.

Some Allentown Observations

When Hulbert and Herring[4] first directed the attention of the profession to the importance of the degree of expansion of the sand bed in filter washing and emphasized the higher efficiency of the more viscous low temperature water, in expanding the media, the authors became interested in the importance of wash water control to secure effective bed expansion under all conditions. To this end Krum, in cooperation with the Simplex Valve and Meter Co., developed the sand expansion indicator, now used successfully in many plants. Data on these studies was first published in WATER WORKS AND SEWERAGE.[5]

For the Allentown experiments a model filter unit with glass sides was constructed. It had an effective area of one square foot and was built to full vertical scale. It was equipped with the perforated concrete Leopold bottom, a duplicate of the block originally installed in the Allentown plant. In other words, the experimental unit is an exact replica of a 12-inch square section of the full size filters—see Fig. 1.

Sand for the experimental unit was taken from one of the plant filters, using a perpendicular column of sand extending from the surface down to the gravel layer. The sand at the bottom of this column had the appearance of clean sand, but the top 8 inches was black in color and had a coating of impurities, approximating 20 per cent by weight. This experimental bed was washed repeatedly, probably 200 or 300 times, at wash rates which expanded the sand in varying degrees up to 60 per cent.

During the course of these experiments on the rate of expansion no new sand was added to the filter; nor, although the unit is equipped to receive coagulated and settled water, was such water applied to the unit. The coated condition of the top sand at the end of the repeated high rate washings in these experiments is revealed in Fig. 1. In the photograph it has the appearance of a layer of black water rather than sand.

At the conclusion of these expansion experiments a fixed jet surface wash of the Baylis type, shown in Figs. 1 and 2 as a perpendicular pipe extending downward and ending 3 inches above the top of sand bed, was installed in the experimental filter to determine whether or not the coating on the sand grains could be removed by this method of washing. The results were startling. The application of the high pressure water jets to the unexpanded sand created a violent movement in the top 8 inches of the bed. This scoured the sand so effectively that the supernatant water immediately became opaque because of the turbidity, and was black in color. After two minutes of this initial scouring of the settled bed, wash water was introduced from below and the entire bed of sand expanded 50 per cent. The resulting downward movement of the upper sand, due to the action of the surface jets, and contact with the upward movement of the lower sand due to the back wash, caused a second violent scouring, with a penetration to 18 inches below the surface. Repeated washing of the sand in the experimental unit by this method resulted in the disappearance of the black coating on the top sand, and the entire volume of sand attained the appearance of uniformly clean sand, as revealed in Fig. 2.

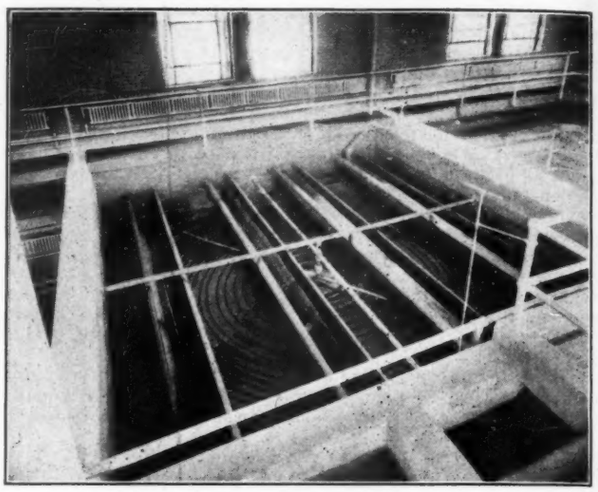


Fig. 3—One of the 1.25 M.G.D. Filters Equipped with Palmer Revolving Agitators.

This demonstration convinced the authors of the comparative inefficiency of the normal method of washing filters. Observations, in other plants have simply confirmed this conviction and further convinced us of the comparative inefficiency of the normal method of washing filters.

Full Plant Scale Data

The Allentown filter plant was built in 1928 and takes water from the Little Lehigh River, a stream draining a fertile farming area, with consequently widely varying turbidities. The works comprise an intake well with screens, low lift pumps, a baffled mixing basin, with an actual retention period of about 20 minutes for floc formation, duplicate sedimentation basins of about 2 hours capacity, and 8 rectangular filter units with a capacity of 1.25 m.g.d. each. Alum is used as a coagulant, with pre- and post-chlorination. The only unusual features of the plant are the non-metallic Leopold Duplex Filter Bottoms. The raw water alkalinity is above normal for Pennsylvania and somewhat hard, but is not grossly contaminated. Some few industrial wastes in minor quantities are present in the water.

The history of the Allentown filter units is typical of many other plants, with probably an average amount of mud ball formation, some gravel disturbance, and an occasional hard spot at the outer perimeter of the units and in the corners. Since the plant was built in 1928 the sand has been ejected from the filters twice for the purpose of breaking up mud balls and to examine the condition of the gravel layers.

Conditions at Allentown, the authors feel, average the field quite generally except for the absence of troubles commonly due to metallic bottoms. The plant is operated at full rates with daily shutdowns of several hours each day.

After due consideration of the condition of the filters and other factors involved, and because of the results observed in the experimental filter, a rotating Palmer Filter Bed Agitator was installed in filter No. 3 in April, 1940. The results were so satisfactory, from a visual standpoint, that four additional filters were equipped with Palmer Agitators, the first being installed in July, 1940, and the last two in April, 1941. The remaining three filters in the plant are likewise to be equipped before the end of 1941.

The surface dimensions of the Allentown filters are 20 feet by 22 feet. The Palmer Agitator installed consists of one brass unit with properly placed jets and with an overall length of 19½ feet, the longest arm used anywhere, according to the manufacturer, up to the time of the last installation. In order to provide rigidity for the agitator, sections of galvanized pipe 2½ inches

in diameter in the form of a cross are fastened to the four walls of the filter with wall flanges—see Fig. 3.

Mud Ball and Coating Reductions

Before the second installation was completed in August, 1940 (filter No. 4), samples of sand were taken from the top 6 inches of the bed and the volume of mud balls accurately measured, using the method advocated by Baylis.[6] In addition, the amount of coating on the sand grains was determined by treating a weighed sample with concentrated hydrochloric acid, washed, dried and reweighed.[7]

These determinations have been repeated monthly since that time. It will be noted in Table 1 and Graph 1 that the average amount of mud balls in the top 6 inches of the seven filters not equipped with agitators was 5.6 per cent. In filters No. 3 and 4, equipped with agitators, after one month of service practically no mud balls remained.

TABLE No. I

Filter	% Mud Balls	Sand Characteristics — Eff. Size	Uniformity Coef.
No. 1	4.3	.63	1.35
No. 2	4.6	.53	1.32
No. 3	0*	.60	1.50
No. 4	7.2	.53	1.40
No. 5	8.3	.55	1.36
No. 6	6.0	.55	1.36
No. 7	2.9	.54	1.40
No. 8	6.1	.69	1.30

*Not tested previous to installation of Palmer agitator. Tests—October 29, 1940.

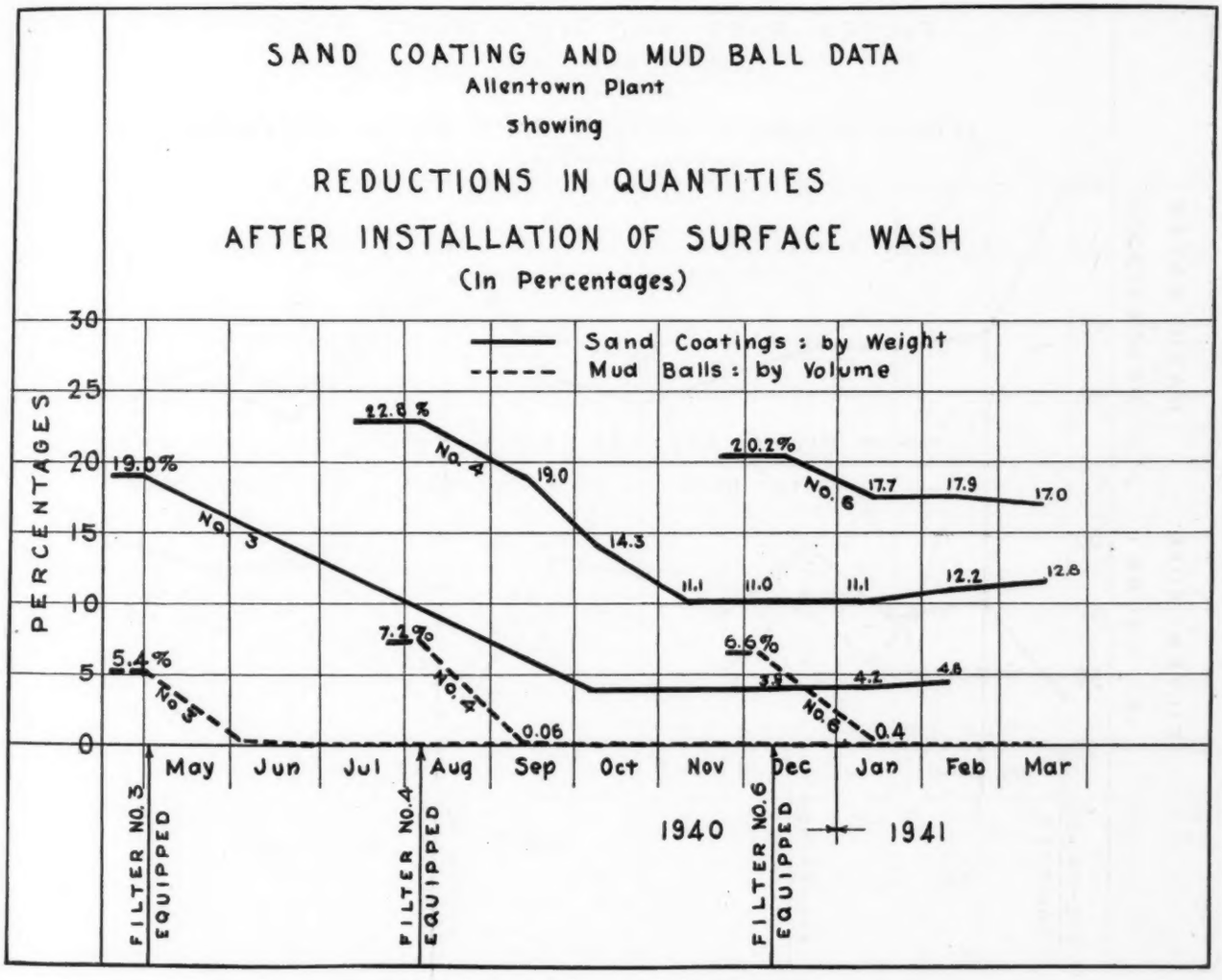
Unfortunately, no sand coating test was made on the sand in filter No. 3 prior to the installation of the agitator. However, the average coating on the sand in filters No. 4, 5 and 6 before the installation of the agitators was 23.4 per cent. The rate of reduction in sand coating, as the result of surface scouring, is shown in Graph 1, which tells its own story better than can be told in many words.

Wash Water Savings

The authors are unable to confirm claims made by others as to marked savings in wash water through the use of surface wash, either by careful analysis of the Allentown plant data or after more general observations elsewhere. It is conceded, however, that other operators may have collected information demonstrating success in this phase of the operations where filter design may not have been as satisfactory—as at Allentown.

At Allentown it has been the practice to wash each filter unit at a loss of head of 6 feet, or immediately upon the appearance of turbidity in the effluent of such filter, rather than to depend entirely on the loss-of-head rate-of-flow, or time period, as variously and generally practiced. Successful coagulation and sedimentation, as well as the turbidity of the raw water, under Allentown procedure greatly affect the length of filter runs. Data on filter runs at the Allentown plant for the year 1940 are shown in Graph No. 2. The effect of spring and fall rains is reflected in the shorter runs in April and November.

In a study of these filter run figures, consideration should be given to the fact that the sand in the plant has been in use for 12 years, and that considerable variation exists in the sizes and uniformity coefficients in the various units because of the gradual and non-uniform loss of the finer particles.. The possible effects



Graph 1—Sand Coating and Mud Ball Records
Revealing Rapidity with Which Surface Wash Removes Sand Coatings and Clears Out Mud Balls.

of these sand characteristics has not as yet been studied in detail.

An examination of the graph on filter runs reveal no definite trend in filter run time, nor does it indicate any reasons for a failure to secure longer runs. The general average of the agitator-equipped filters is approximately that of the other units. The high percentage of wash water used for filters No. 3 and No. 4 in the first months after installation of the agitators in these units, undoubtedly was due to frequent washing for demonstration and experiments, rather than to normal procedure.

From the standpoint of increased length of filter runs, therefore, no savings in wash water have been secured at Allentown. The same general impression seems to have been arrived at in other plants under observation, without any definite figures available for confirmation. A lower sand expansion index has been used at Allentown in the agitator-equipped units than in those not so equipped, but the saving in wash water which apparently should be effected has not been confirmed by actual measurement and plant data.

At Allentown, as previously stated, prechlorination is a regular practice. One of the gains effected through the surface wash installations and a further indication of the increased cleanliness of the media in the units so equipped has been the greater residual chlorine maintained in the effluents of these filters, as compared with the effluents of the remaining filters. Data are shown in Graph 3.

Chlorine Economy

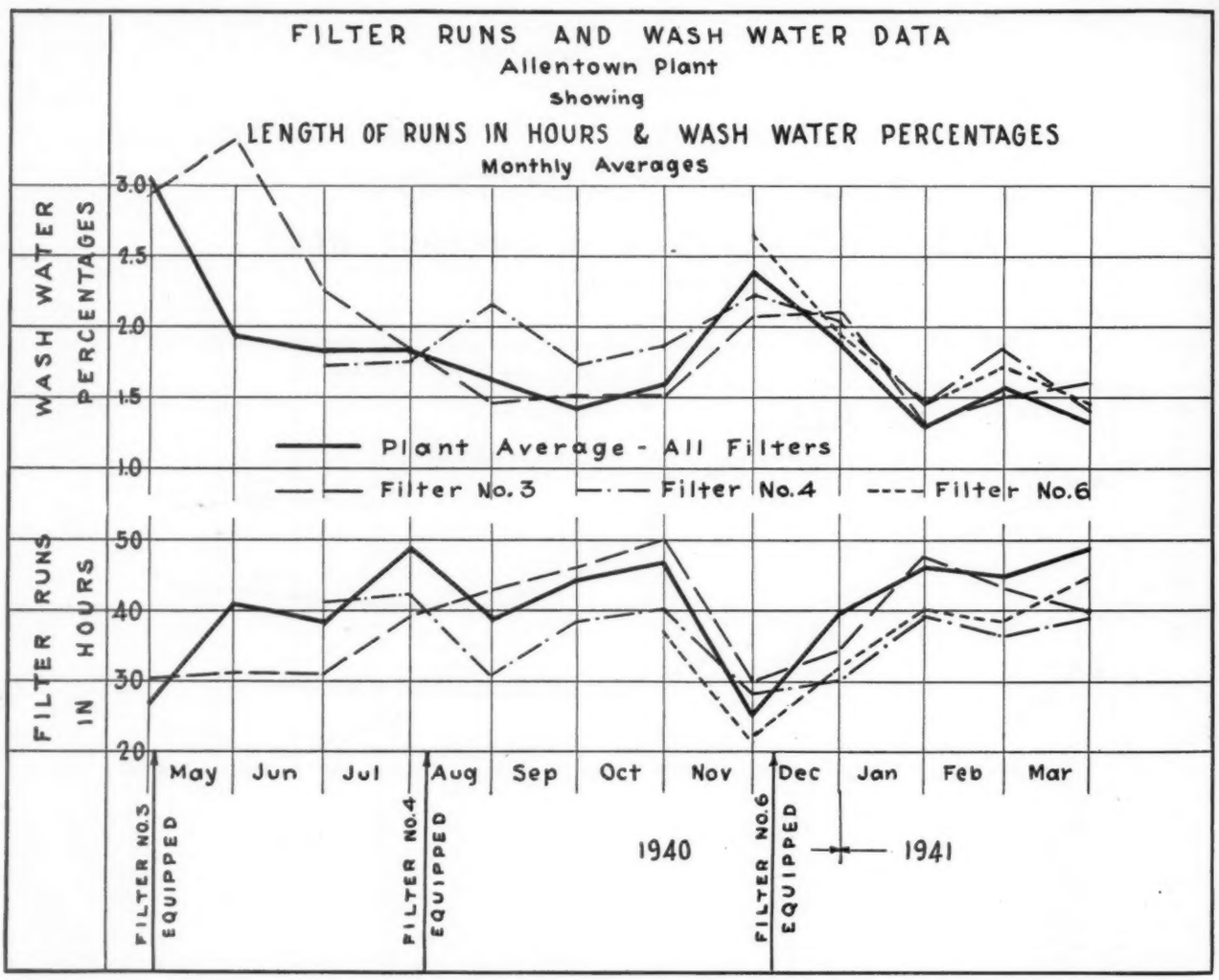
It will be noted that the chlorine residuals in the effluents are uniformly and consistently greater for agitator equipped units No. 3, 4 and 6 than for the other units not so equipped. On many occasions the residual of these units has shown very little reduction from that of the residual of the applied water. In actual practice this means eventually a decrease of appreciable amount in the rate of application of pre-chlorine, with subsequent savings in expenditure for this chemical when all filters have been equipped with surface wash facilities.

This effect of the cleaner sand on chlorine residuals (chlorine absorption by the bed) was first noted in December, 1940, some six months after the first agitator was installed in filter No. 3 and three months after No. 4. Detailed studies and observations on the residuals of the separate units was then begun and have since been continued.

The heavy chlorine demand of the average filter unit is well known, and it is sometimes difficult to secure any residual chlorine through a filter bed unless the sand is super-chlorinated before pre-chlorination is begun, or until heavy pre-chlorination has been practiced for some considerable period of time. As a matter of fact, many an operator has been brought to grief through the application of pre-chlorine to dirty filters because of subsequent severe taste and odor production resulting from reactions between the chlorine and accumulations within the ineffectively washed sand bed.

At Allentown all filters were thoroughly chlorinated before pre-chlorination was begun. Prior to the time the first agitator was installed, application of chlorine in doses up to 1.14 lbs. per million gallons had been used continuously for approximately 12 months, with the point of application at the influent of the mixing chamber, approximately three hours before the chlorinated water reached the filters.

The decreased chlorine demand of the filtering media after the agitators were installed became apparent almost immediately in filter No. 6, and after about two months of operation, the residual of this unit reached approximately the same figures as for those



Graph 2—Filter Run and Wash Records
(These Records Fail to Show Wash Water Reduction Accruing from Surface Wash at the Allentown Plant.)

of filters No. 3 and 4, which had been surface washed for about 6 months and 4 months, respectively, prior thereto.

The authors hope to make a detailed study of this problem—the chlorine demand of filter media—in the near future.

Costs of Installation

The effective apparatus of the agitators, consisting of a toggle joint, pipe manifold, and special nozzle openings, all of brass, was purchased at a cost of $197.64 for each unit at Allentown. Auxiliary valves and pipings were purchased by the city and installed by the salaried employes of the city. Basing the labor costs, however, on current hourly rates for skilled mechanics, and adding in the costs of piping, valves, etc., the total cost of installation for one unit (1.25 m.g.d.) was $310. This would mean a total cost of about $2,500 to equip all eight filters in the plant.

In this cost analysis, consideration must be given to the fact that the Allentown filter boxes are almost square in plan (20 by 22 feet), so that it was possible to use only one revolving mechanism to each unit. With filters of dissimilar area, the costs may be greater because of the necessity for installing two or more arms in each bed to cover the entire area. Apparently a reasonable average cost figure, for general use, might be given as $350 per M.G.D. of filter capacity.

Summary

1. To a greater or lesser degree, mud-balls and hard spots are common to rapid sand filter units.

2. Despite careful design, careful operation, and a multitude of practices, no generally successful method of preventing these disturbances had been found prior to the development of the surface wash by Baylis about 1930.

3. In all plants where surface wash has been made an auxiliary to normal bottom wash, improvements in the appearance and cleanliness of filter media have been made.

4. Surface wash piping or the revolving Palmer agitator can be installed without any major interference with normal filter operation.

5. Costs of installation of the Palmer Agitator depends on the size and shape of the filter boxes, but generally speaking, should average about $350 per M.G.D. capacity, including all costs for labor and appurtenances.

6. At Allentown, Pa., with a Palmer Agitator to provide surface wash:

a. Mud balls were practically eliminated in five weeks' operation of a full scale unit.

b. Coating on sand grains was materially reduced.

c. No appreciable saving in wash water has resulted through the use of surface agitation.

d. With pre-chlorination, the effluent of agitator equipped filter units show continuously higher chlorine residuals than do the units washed at high rates but without surface agitation.

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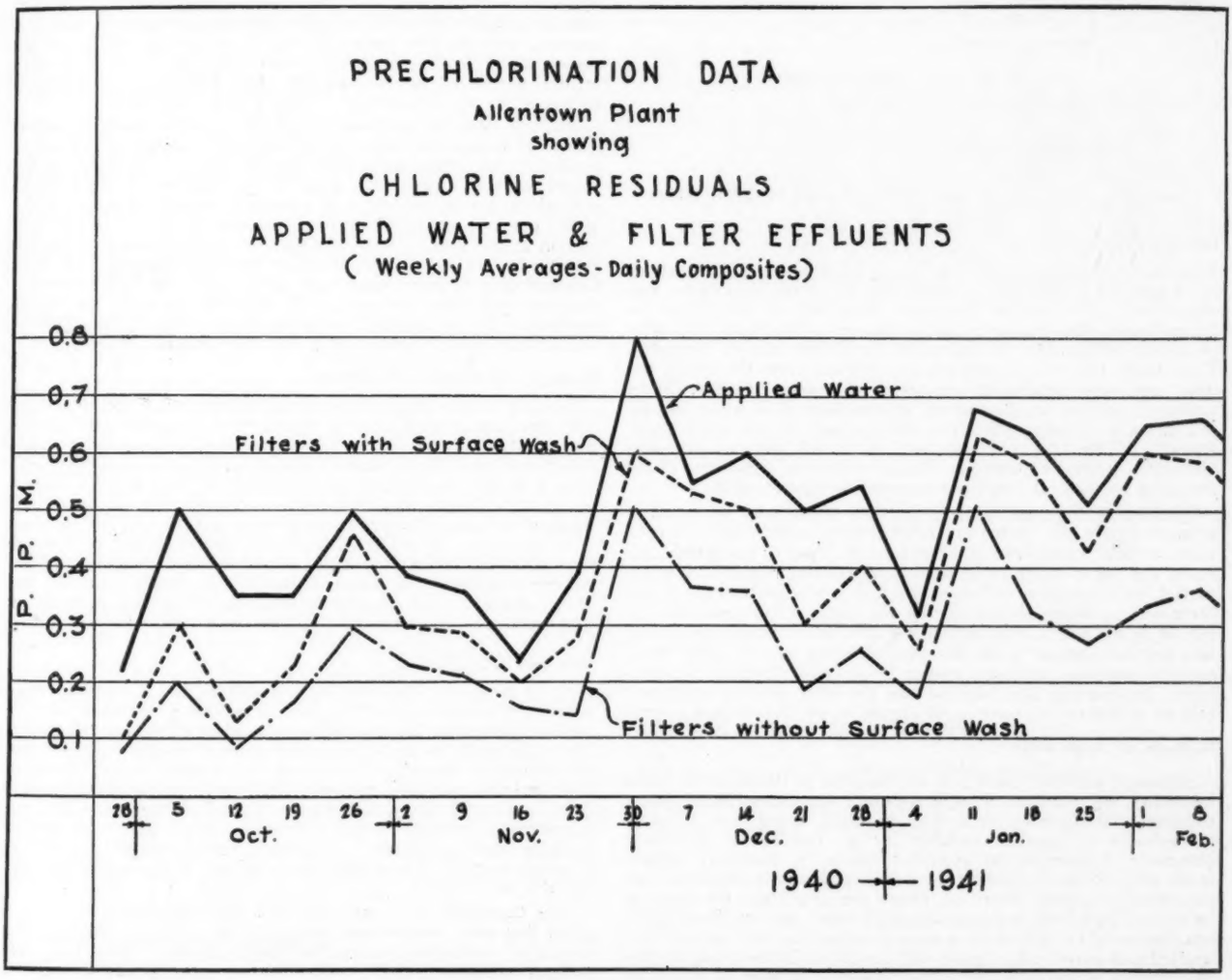
5. Krum & Jones; W. W. & Sew., Vol. 84, No. 10. Oct., 1937.

6. Baylis; W. W. & Sew., Vol. 82, No. 9. Sept., 1935.

7. Krum; Jour., Penna. W. Wks. Operators Assn., Vol. 10, 1938.

filter No. 6, and after about two weeks of operation, the residual



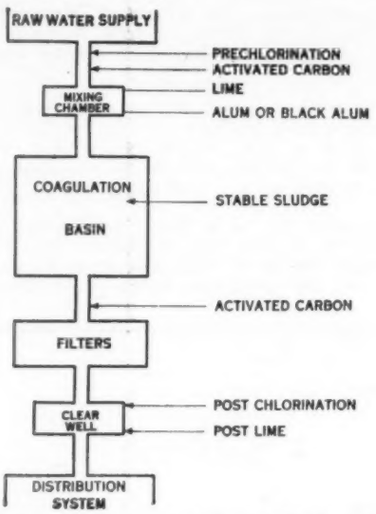
Graph 3—Records of Chlorine Removal by the Filters.
(Indicating the Extent to Which Chlorine Is Absorbed by Coated Sand vs. Clean Sand in Those Filters Equipped with Palmer Agitators—in Itself an Index of Sand Cleanliness as Well as an Operating Economy Realized.)

ACTIVATED CARBON IN TASTE AND ODOR CONTROL

By E. A. SIGWORTH

*Industrial Chemical Sales Div.**
New York City

Progressive men in the water works field realize that by serving the public a water that is palatably attractive, as well as safe they are doing a real and appreciated service to the community. Toward this end activated carbon has filled a very real need, and now the use of the adsorptive purifying material has grown the world over. In speaking of "tastes and odors" in water it is well to keep in mind that we are principally concerned with odors rather than tastes.



Flow Sheet for Chlorine and Activated Carbon Applications

The Material

Activated carbon, as it is usually employed in water purification, is a fine black powder and accomplishes the removal of tastes and odors by a phenomenon commonly described as adsorption. In simple terms this means a concentration of the taste and odor producing substances on the surfaces of the carbon particles. Thus, when the carbon particles are removed from the water, the taste and odor producing substances are also removed. Since activated carbons are harmless, an overdose in a water supply will cause no greater difficulties than perhaps to add some slight amount to the cost of treatment. Activated carbons are also offered in granular form for contact units—in situations where the more economical powdered material is unpracticable.

Considering the great variety of odors which may be found in a water supply, the almost universal success in removal with activated carbon is truly remarkable. John R. Baylis[1] has stated "All tastes and odors likely to be present in a water supply can be removed with activated carbon.—We find a few statements in the literature on water treatment that the taste or odor was not removed by the addition of carbon, but almost invariably the reason was that not enough carbon was used." Along with its other many accomplishments, activated carbon is a very effective dechlorinator. Its use for this purpose has the very definite advantage that an overdose will have no ill-effects in the distribution system.

Methods of Application

Although activated carbon is not harmful to health when taken internally, its presence in a distribution system could be objectionable to the layman because of its black appearance. Thus, it is desirable to plan in advance for its removal in treatment processes. Application of activated carbon is therefore usually made prior to sand filtration. However, activated carbon has been successfully applied where no filters are available; the removal being accomplished by coagulation and sedimentation. Even where coagulation is not practiced, activated carbon has been successfully applied and removed by simple sedimentation. There are a number of instances where activated carbon has been applied in reservoirs without any coagulating aids and the carbon has been allowed to settle out of the water. Even if this method of application is not practical, there is still the granular form which can be utilized in a filter system or packed between screens through which the water is passed. Granular activated carbon has also been employed in bags, which are suspended at suitable points in the water system, whereby the water has an opportunity to come in fairly intimate contact with the carbon particles. However, activated carbon is most frequently applied in water systems where sand filters are available.

The powdered carbon can be applied by means of either solution feed or dry feed equipment. A survey made a few years ago showed that the most general feeding method employed was with dry feed equipment. Today practically every manufacturer of dry feed equipment has placed machines on the market that are specifically designed to feed activated carbon from minute quantities up to unusually large dosages.

Points of Application

No definite rules can be laid down for the proper point of application in order to secure optimum results. Conditions within the various water plants vary to so great an extent, from the viewpoint of equipment, design, types of water, types of pollution, and intensity of tastes and odors, that the best means of determining the proper point of application seems to be by a trial and error method.

The above mentioned survey revealed that the point of application most commonly utilized is prior to, or during coagulation. When activated carbon is applied at this point, it has a longer time in contact with taste and odor producing substances, and also carriers through the basins giving a stabilizing effect on the sludge which settles out. Where tastes and odors are of a more serious nature or occur regularly, the application of activated carbon prior to sedimentation seems to be desirable.

In some cases it has been found that greater efficiency in removal of tastes and odors is accomplished when the carbon is applied to the settled water entering the filters. Conditions, which would seem to justify this point of application, are mild tastes and odors; tastes and odors of a periodic nature, or severe tastes which come up quickly but are discovered in time to permit correction at this point. Heavy dosages of carbon cannot be applied directly to the filters without adversely affecting the filter runs. Consequently, if high dosages of carbon are necessary to correct the taste and odor condition, it is advisable to apply the carbon prior to or during coagulation, or to utilize a split dosage; namely, both to the filter influent and to the raw water.

Dosages and Costs of Treatment

Because of the varying types and concentrations of taste and odor producing substances in water, it is impossible to predict the quantity of activated carbon necessary to correct an individual condition. Experiences have shown that dosages may vary from 1 lb. per million gallons to as high as 2,000 lbs. per million gallons. Extremely high dosages of activated carbons are usually required for only short durations of time and particularly on types of odors which are rather difficult to remove. Based on average taste and odor conditions, a dosage of 20 to 50 lbs. per million gallons is sufficient to insure delivery of palatable water. It has been calculated that the average cost of activated carbon would represent only approximately 3c per capita per year.

Threshold Odor Test

As a means of determining the degree of palatability of a water, the threshold odor test was developed by Charles Spaulding of Springfield, Illinois. In this test odors are compared against odor-free water in such a way that a definite number, measuring the individual intensity, is secured. By means of the threshold odor test it is possible in water works practice to pre-determine fairly accurately the quantity of activated carbon necessary for treatment in order to furnish a palatable supply to the consumers. As a result many plants have adopted the threshold odor test as a routine method of procedure on samples of water taken throughout the entire plant.

The threshold odor test has now been developed to such a point that with proper care and precision it can be utilized as a means of evaluating various activated carbons. Thus, with this method available, water works operators can assure themselves that they are purchasing that quality of activated carbon which will most economically remove tastes and odors from their individual supply.

* A Division of the West Va. Pulp and Paper Co.
[1] John R. Baylis, Elimination of Taste and Odor in Water—McGraw-Hill Book Company—1935.

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Anthafilt and Its Application

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Anthrafilt is used as a mechanical aggregate in place of sand and gravel in all kinds of filters, i.e.

Rapid gravity filters	Slow filters
Swimming pool filters	Pressure filters
Hot process softening filters	Oil removal filters
Cold process softening filters	Alkali filters
Mechanical sewage filters	Acid filters
Revolving screen filters	Sewage sludge-beds
Portable filters	Household filters

The entire filter bed may be made up of Anthrafilt of various sizes or only the top layer may be of Anthrafilt over the usual bed of gravel.

Advantages of Anthrafilt

High Filtration Rate: Rates up to 200 mgad are obtainable with Anthrafilt without sacrifice of effluent quality. The accepted average rate with sand is 125 mgad.

Long Filter Runs: The larger, irregular Anthrafilt grains allow less clogging with algae or other fibrous substances. The angular grain surfaces provide greater entrapping areas for the removal of turbidity and bacteria. The differences in shape and specific gravity of the grains, by decreasing classification after back washing, allow the whole depth of the filter bed to be active in the filter operation.

Low Wash Water Costs: The long filter runs and consequent less frequent washing and the low degree of packing after back washing combine to cut the usual wash water requirements at least in half.

No Cementing with Lime, Manganese or Iron: Lime will coat on Anthrafilt but this coating readily flakes off without any cementing action if filters are properly operated. Manganese and iron salts precipitated on Anthrafilt by the lime treatment are easily removed by back washing.

High Degree of Expansion: 50% expansion is obtained with half the back wash velocity required for sand.

Coarse Sizes Can Be Used: The irregular shape and natural filtration characteristics permit the use of much larger sizes with equal results.

Gravel Beds Stay Flat: No ridging or mounding and less cracking and pulling away from side walls during operation.

Low First Cost: Lighter weight per unit volume balances the cost differential between Anthracite and sand and saves on freight and handling charges.

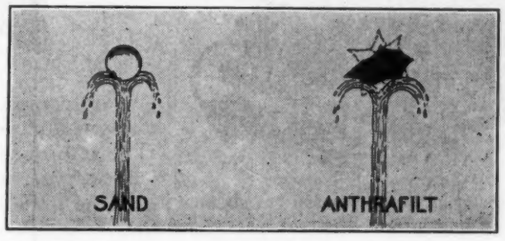
Filtration Characteristics

Anthracite granules are irregular shaped and of varying densities. Weights run about 53 pounds per cubic foot as against 100 pounds for sand. The irregular shapes provide greater porosity resulting in more rapid filtration with no loss in character of effluent and with considerably less loss of head.

The variable densities of Anthrafilt particles cause less classification after back washing and the lighter, irregular shapes allow easier expansion and more effective cleaning.

The greater bulk of Anthrafilt requires less tonnage per filter bed. Attrition losses amount to less than 0.25% per year.

Anthrafilt successfully removes lime, iron and manganese salts and will not form a permanent coating under proper conditions of treatment and filter operation. Lime flakes off easily without cementing and the iron and manganese salts are readily removed by back washing. Oil is easily removed from boiler water after coagulation with ferric sulphate, ferrous sulphate or alum. Anthrafilt can also be used for the filtration of acetic and sulphuric acids and caustic soda solutions. Being insoluble in alkaline waters, Anthrafilt produces silica-free water in hot process water softening.



Upward impulse of water produces greater agitation of angular grains, hence Anthrafilt beds are cleaned more effectively.

Anthrafilt No. 1 is usually made in sizes ranging from effective size of .60 m.m. to .80 m.m. the uniformity coefficient is less than 1.75 in all cases. We can make smaller sizes or larger sizes, but for special cases only. The remaining sizes of Anthrafilt are as follows:

No. 2. Anthrafilt—3/32″ x 3/16″
No. 3. Anthrafilt—3/16″ x 5/16″
No. 4. Anthrafilt—5/16″ x 9/16″
No. 5. Anthrafilt—9/16″ x 13/16″
No. 6. Anthrafilt—13/16″ x 1-5/8″
No. 7. Anthrafilt—1-5/8″ x 2-7/16″
The above sizes have 20% tolerance.

ANTHRAFILT ECONOMY

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Increased capacity with same plant
Decreased volume of wash water
Lower maintenance cost through elimination of ridging, mounding and air binding.

When Used in New Filtration Plants

Lower plant investment
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Lower wash water costs
Lower maintenance costs

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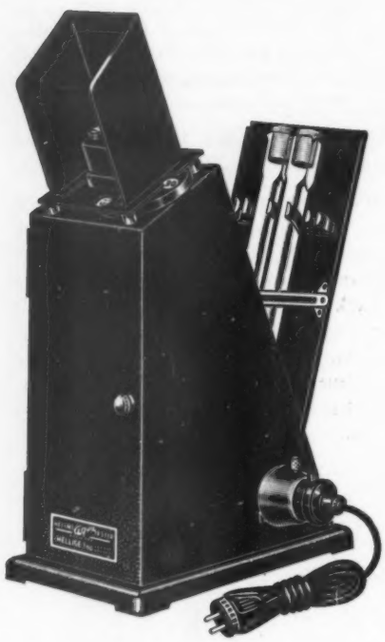

HELLIGE COLORIMETRIC COMPARATORS employ glass color standards which are non-fading, and therefore permanently reliable. There is no doubt whether these standards are "still good"; there is NO GUESSWORK. Hellige glass color standards never fade or change, never fail. Being made of colored glass, which has, for other uses, maintained its color stability for ages, they are the only standards which can logically carry a lifetime guarantee of accuracy. Glass standards are economical: bought once, they serve for practically an unlimited period, and thus quickly pay for themselves by the saving in time, chemicals, replacement cost, and other expenses encountered in the use of liquid standards. The standards occupy a minimum of space, and are the easiest to manipulate.

The comparators, with which the glass standards are used, are unique in design, and offer more conveniences than any other similar testing outfits. The improved model of Hellige Aqua Tester is shown at the left. The inclined construction for working in a natural sitting position, color fields in juxtaposition, and Nessler tubes with plano-parallel bottom plates are some features of this improved water tester.

The three small illustrations show the Hellige Pocket Comparator. It is the handiest and smallest instrument ever brought on the market for accurate hydrogen ion measurements and water analysis. The durable corrosion-resistant housing holds all parts necessary for a test, as revealed by the left and right hand illustrations which show the comparator with front and rear covers opened. The size of the complete apparatus is only 3¾ x 3¾ x 1½". For both comparators, glass color standards are available for all popular pH indicators, and for the determination of color of water, ammonia nitrogen, nitrate nitrogen, chlorine, iron, dissolved oxygen, manganese, lead, phosphate, silica, and sulphides.

The HELLIGE TURBIDIMETER

A Turbidimeter *Without Standards* for Water Analysis and Sulfate Determinations

Illustrations show the observation fields: the one in the center shows the balanced field, after the proper adjustment of the slit by means of the drum knob; the end ones show the unbalanced fields.

This apparatus is based on the comparison of the Tyndall effect on the test liquid with a beam of light passing through the same suspension. Therefore, the use of standard suspensions which are tedious to prepare, and do not retain their original value, is entirely overcome. The comparison fields are distinctly differentiated so that measurements can be made with utmost convenience, simplicity, and speed, and correct results are obtained by anybody without special training for this type of work. Tubes of different liquid depths are available for turbidity measurements from 0 to 150 p.p.m. SiO_2, and sulfate determinations from 0 to 100 p.p.m. SO_4.

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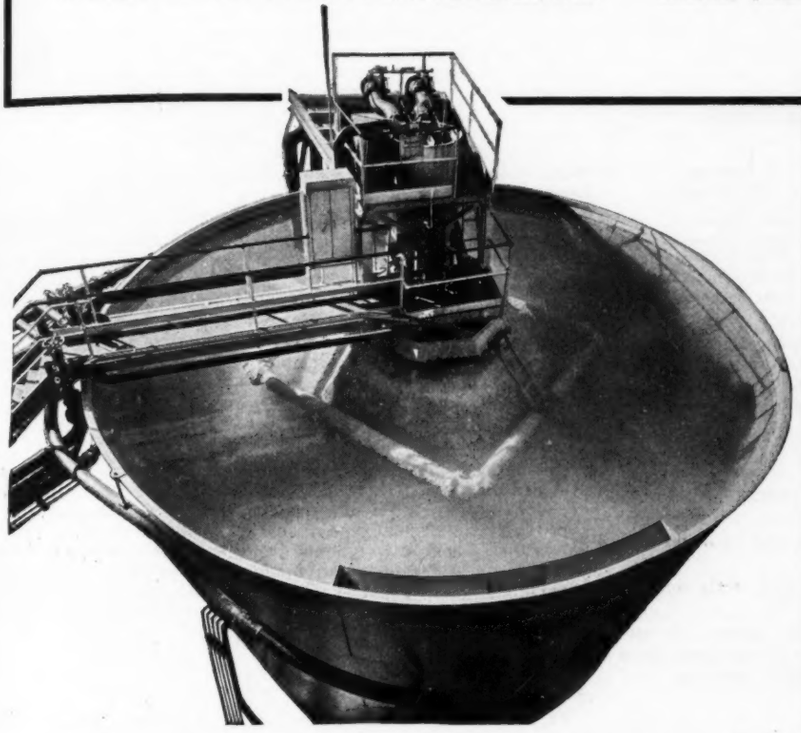

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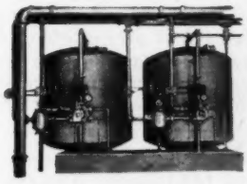
This revolutionary new equipment removes hardness and suspended solids in a much shorter detention period, saves chemicals, takes only half the space of old-type plants. The raw water and chemicals are mixed in a compartment where they are agitated with the suspended sludge from previously treated water. This speeds precipitation. The water and precipitates then pass into the filter upflow compartment which has a gradually increasing cross-section. The gradually reduced velocity of upflow supports the sludge filter at uniform density throughout the filtering zone. A rate of flow is reached at which the sludge is no longer supported, but drops sharply out. The effluent is clear, and may not need further filtration.

Permutit makes every type and size of water conditioning equipment. Here are a few:



ZEOLITE WATER SOFTENERS

In Permutit's pressure zeolite softeners, a single multi-port valve, operated automatically or manually, conducts the raw water into a shell, distributes it evenly through a bed of zeolite and collects it, the water flowing to service completely softened. The valve also controls backwashing to clean the bed, regeneration with brine, and rinsing. Gravity zeolite units are also available.

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Automatic and manual, gravity and pressure.

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WATER CONDITIONING HEADQUARTERS

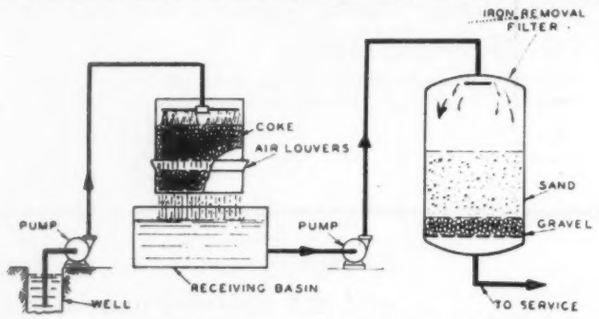
REMOVAL OF IRON AND HARDNESS

By DANIEL J. SAUNDERS

The Permutit Company, New York, N. Y.

The following describes some of the difficulties experienced in industry and in the home due to the presence of iron and hardness in water and, at the same time, outlines methods that can be employed to overcome such difficulties, under varying sets of conditions.

When iron is present in a water supply in an amount greater than 0.3 p.p.m., it causes unsilghtly yellowish or black stains on bathroom fixtures, gives a metallic taste to drinking water, reacts with other reagents used in dye houses, laundries, paper mills and tanners where, for example, it combines with tannin in leather and forms black iron tannate; deposits in Municipal distribution systems, thus not only increasing the friction through



A Simple Coke Aerator and Iron Removal Filter.

the mains which increases pumping costs, but at sudden high rates of flow these deposits loosen iron rust itself which is delivered to the users. Further, the growth of iron bacteria, such as Crenothrix, is also promoted by its presence.

The type of treatment plant required to remove iron is determined by a number of factors such as: character of the water (especially the factors interfering with oxidation reactions) engineering conditions and the purpose for which the water is to be used.

Iron and Manganese Removal

In general, iron (also manganese), can be removed from well waters by two methods:

1—Oxidation to the insoluble higher oxides and hydrates followed by filtration.

2—Removal by base exchange, by employing correctly selected base exchange zeolites.

However, all waters and particularly surface supplies, do not respond readily to oxidation reactions. As just mentioned, there are interfering factors to be given consideration such as:

Free Carbon Dioxide

High amounts of free CO_2 or any acid will interfere with the oxidation reactions going to completion. Therefore, in such cases thorough aeration, or addition of alkalis, or both, are necessary. The addition of only 0.14 p.p.m. of oxygen per 1 p.p.m. of iron is theoretically required in the normal oxidation reaction. This quantity is insufficient when free CO_2 or any acid is present.

Low Total Solids

With waters of this type usually, even though a thorough removal of the carbon dioxide is effected by efficient aeration, it is necessary to supplement that step in the treatment by additional steps, as will be described later.

Organic Matter

Iron or manganese present in organic combinations is not removed by simple aeration and filtration. Coagulants fed into floc forming aggitating devices to accelerate floc formation and sedimentation tanks or basins must precede the filters.

Excessive Aeration

This has been known to interfere with the complete removal of iron and especially manganese. In such cases, restricting the aeration, i.e., limiting the absorption of the oxygen to a fraction of saturation, gives better results.

Types of Plants

Waters Low in CO_2 and Relatively Low in Iron Responding Readily to Oxidation

A small amount of air can be introduced by sniffling air into the suction side of the well pump for oxidation purposes. The well pump can then pump the oxidized water directly through either a single pressure filter or, to avoid frequent backwashings, through a coarse pressure filter followed by fine pressure filter direct to storage or use, thus making repumping unnecessary.

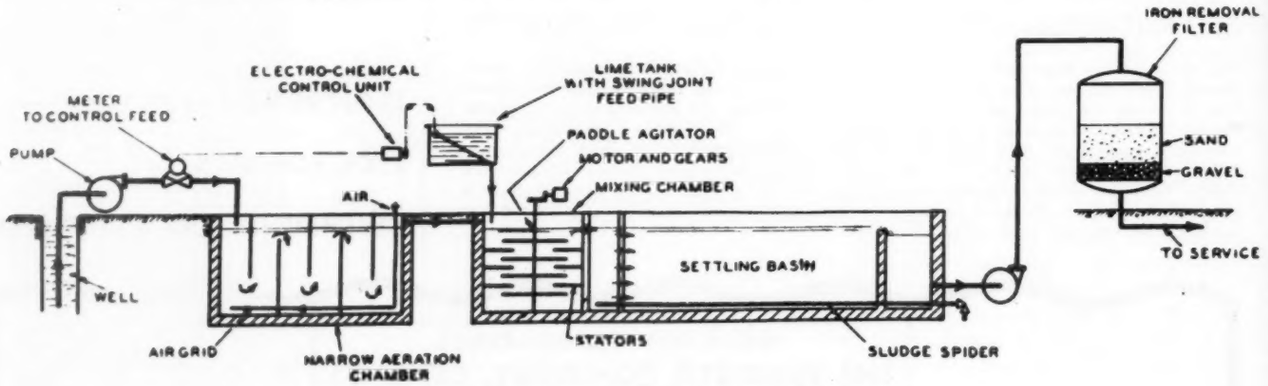
However, where preferred, gravity filters can be employed. Air wash systems should be employed where their use is deemed advisable.

Waters High in CO_2 Requiring CO_2 Removal by Alkali Feed or Efficient Aeration Before Final Filtration

In this case, the arrangement just described can be employed provided an alkali feed is installed to neutralize the CO_2. However, as air is free, if the quantity of water being pumped is appreciable, an efficient type of aerator should be installed, preferably either a coke tray type or degasifier bubbling type to insure exposing the water to the air in thin films or drops so that each particle of water contacts air low in CO_2 content. However, should the iron present in the raw water be very high, a sedimentation tank or basin may be required.

Waters of Low pH Value That Do Not Respond Readily to Oxidation

In such cases, following aeration, lime or soda ash is fed by means of a proportionating chemical feed to a sedimentation tank or basin (equipped with floc formers for aggitating purposes).

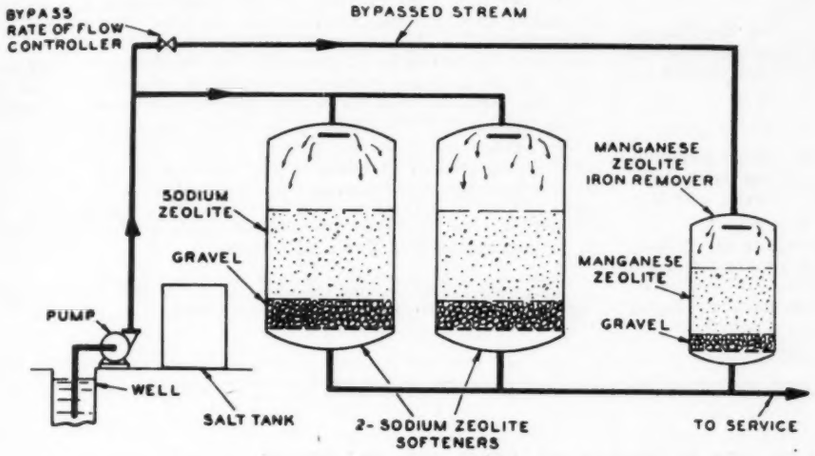


Iron Removal System Providing Flocculation.
Involving aeration, lime treatment, flocculation and clarification before filtration.

Lime is employed for the larger plants—soda ash for the smaller plants. Lime gives better results because it also has a coagulating effect. However, it also increases the hardness and as this is objectionable in many cases, soda ash is employed. The settled water is then pumped through filter equipment to either the mains direct or to storage and the mains.

Waters Containing Iron in Organic Combinations

The treatment suited to any given case of this kind will depend upon the type of organic compound present. The best treatment must be determined by experiments in the field and the laboratory. Further, the treating plant should be designed so that the pH values may be altered at will and also so that different coagulants may be added as required.



Combination Zeolite Softener and Manganese and Iron Removal Zeolite Units. Capable of producing iron free effluent of 4 to 5 grain hardness—favored in municipal installations.

Obviously, this will mean equipment for feeding various chemicals, sedimentation (and possibly double sedimentation) and filtration, plus chlorination.

Waters of Low Iron Content Where Reduction in Iron Content Should Be Below 0.1 ppm.

Manganese zeolite filters are most effective in the removal of iron where practically complete removal is desired for industrial purposes. Manganese zeolite consists of sodium zeolite treated by manganous chloride and oxidized by sodium or potassium permanganate. The manganese zeolite proper acts as an active carrier and catalytic reagent. The oxides themselves do the work of iron removal. These oxides give up oxygen to the water for the necessary oxidation reactions. They are re-oxidized by passing permanganate solution through the bed. Approximately 0.01 lb. of permanganate per thousand gallons is required for the average water. These filters are backwashed daily, but usually regenerated only at weekly intervals.

Sodium zeolite of the natural type, provided it has been correctly processed, or "Zeo-Karb" material, a carbonaceous zeolite, may be economically employed to remove iron and manganese by base exchange, at the same time that the zeolite is softening the water. When these types of zeolites are employed for iron and hardness removal by base exchange, the iron must be maintained in the *ferrous* form. Therefore,, well waters cannot be exposed to air before such zeolite treatment. The regeneration of units of this type is accomplished by the usual sodium chloride regeneration employed in zeolite softening.

Water Softening

There are five methods of water softening in general use. These are:

1. Zeolite Process—Sodium Cycle.
2. Zeolite Process—Hydrogen Cycle.
3. Cold Lime Soda Process.
4. Combination Lime Zeolite Process.
5. Hot Process.

Processes Nos. 1, 2 and 4 will reduce the hardness of the water to practically zero. Process No. 3, depending on the way it is carried out and also the composition of the raw water, will reduce the hardness from 3 to 5 grains per U. S. gallon. Process No. 5 will reduce the hardness to some figure below 1½ grains per U. S. gallon, depending upon the character of the water, the chemicals employed, etc.

Zeolite Process (Sodium Cycle)

With this method the hardness is removed by base exchange; the calcium and magnesium being retained by the zeolite while the corresponding sodium salts are found in the effluent. After the rated capacity of the zeolite to soften water to zero hardness has been exhausted, the softening capacity is restored by treating the zeolite with a solution of common salt.

As this salt solution comes in contact with the zeolite, the calcium and magnesium is removed in the form of the soluble chlorides, and its original sodium content is restored. After flushing the chlorides of calcium and magnesium, plus excess salt, to the drain, the zeolite is ready to soften a further equal quantity of the hard water.

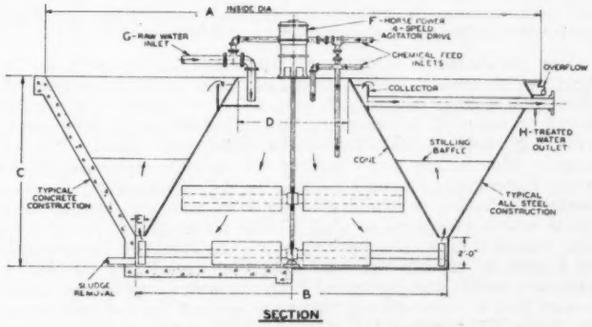
These alternate softening runs and regenerations can be repeated indefinitely, as the wear and tear on a correctly processed zeolite is negligible. Therefore, the annual cost of replacing this zeolite is correspondingly low. The effluent from a zeolite water softening plant is practically of zero hardness. As zero hardness water is either a requirement or at least desirable for most industrial processes, all of the water used in an industrial plant is usually passed through the zeolite plant. In the case of municipal zeolite plants, a zero hardness water is not required. Therefore, in such cases, enough hard water is bypassed and mixed with the zeolite softened water to yield a mixed effluent of the desired degree of hardness.

Zeolite water softeners are available to operate automatically through all cycles of operation by a combination of a motor driven multiport valve with electrical controls. Automatically, the equipment is cut out of service. backwashed, brined, rinsed and returned to service. About 90% of the more recent municipal zeolite water softening plants are of the automatic type.

Zeolite Process (Hydrogen Cycle)

In this process of water softening, a carbonaceous type of zeolite is employed. It is of especial value in softening waters of a high bicarbonate content, as the bicarbonates, of sodium, calcium, or magnesium, are replaced by carbon dioxide and water; the base being retained by the zeolite.

The carbon dioxide may then be removed by passing the softened water through a degasifier (bubbling) type of aerator. This process, therefore, in a very simple manner practically completely removes bicarbonates of all kinds.



Section Through the Spaulding Precipitator. The treated water is mixed with sludge (center) and rises upwards through the sludge blanket to the surface overflow.

At the end of the softening run, the carbonaceous zeolite is regenerated by treating it with a dilute solution of sulfuric acid. This restores the hydrogen content of the zeolite and simultaneously removes the bases in the form of soluble sulfates. These,

plus the excess of acid, are then flushed out to the drain, after which the zeolite is ready for the next softening cycle.

Cold Lime Soda Process

In this process, as carried out in the conventional type of equipment, the raw water is treated with regulated dosages of lime and soda ash. The bulk of the hardness precipitated by these chemicals, is then settled out in a settling tank having a detention period of at least 4 hours.

It is then either recarbonated and filtered or filtered and recarbonated. As usually carried out, the effluent so produced has a hardness of 5 grains per gallon.

In the relatively newer Spaulding Precipitator type of equipment, the treated water is brought into intimate contact with suspended sludge. This suspended sludge acts to produce a more stable effluent in a much shorter period of time.

In practice, it has been found that the Spaulding Precipitator requires only a one hour detention period and that the reduction of hardness is so complete that recarbonation is either carried out to a very slight extent or eliminated.

Combination Lime Zeolite Process

In the combination lime zeolite process of water softening, the bicarbonate hardness is reduced by treatment with lime. The lime treated water is then recarbonated, filtered and then passed through zeolite water softeners.

The net effect is that the lime treatment removes the bulk of the bicarbonate hardness and the subsequent zeolite treatment removes the non-carbonate hardness plus any residual bicarbonate hardness. In many cases, it has been found economical to employ this combination type of treatment because of the savings effected in the lower cost for salt vs. soda ash required per 1,000 grains of hardness removed.

For industrial processes or boiler water, all of the lime treated water is passed through the zeolite water softeners. Incidentally, when *any* water is used for boiler feed, it is important to give consideration to supplementary treatment so that the final reedwater will conform to modern power plant practice, as prescribed by the ASME. For municipal water supplies, only the requisite portion of lime treated water, required to produce a 4 to 5 grain per gallon hardness in the mixed effluent, is shunted through the zeolite water softening equipment and again joins the lime softened portion.

Hot Lime Soda Process

The hot lime soda process of water softening is carried out by adding carefully regulated dosages of lime, soda ash and/or other chemicals to the raw water, after heating it to a temperature at or near the boiling point. Since the high temperatures employed speed up the chemical reactions, a detention or settling period of only one hour is required. (This statement indicates the value of the Spaulding Precipitator which requires no heat input.)

The settled water is then filtered through filter beds of non-siliceous material. Depending on the excesses of chemicals used, the hardness of the effluent varies from as low as 1½ grain per gallon down to a fraction of a grain. As this process must be carried out hot, its application is obviously practically limited to the production of boiler feed waters.

* The content of this article is in part derived from a paper read by the author before the Michigan Section of A.W.W.A. and Michigan Conference on Water Purfication meeting jointly.

SOLVING CHLORINE ICE TROUBLE

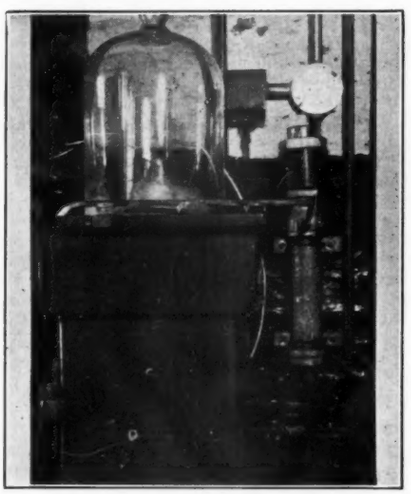
By DON CALDERWOOD, Engr.
Pennichuck Water Works Co.
Nashua, N. H.

IF you have had trouble with chlorine hydrate—usually called chlorine ice—forming in your chlorinator, you may be interested in hearing how we solved this problem.

A few years ago we purchased a Wallace & Tiernan type MCVM chlorinator. The following winter we experienced our first real trouble with so-called chlorine ice. We built a wooden box over the bell jar and put electric lights in it; we tried a unit from a sun bowl heater inside the standard under the tray; and then a combination of both. These gave results after a fashion but did not do a real workmanlike job—so after three or four seasons of makeshift operation we set out to find a permanent solution to the problem.

We purchased a 1,500 watt immersion heater with a three heat switch giving us 500, 1,000, or 1,500 watts as needed. We then took a piece of 2½ inch pipe about 10 inches long, screwed a cap on one end, a reducing coupling on the other, and into the reducing coupling we screwed the 1,500 watt heater. We next tapped into the cap and coupling for ⅛ inch copper tubing and after fastening the assembled unit to the chlorinator we disconnected the water supply line to the tray and with copper tubing made new connections so that all the water going into the tray first passed through the heating unit. To eliminate the possibility of forgetting to turn the heat either on or off, we purchased a pressure switch and connected it to the water supply line in such a way that it automatically turns the current for the heating unit on when we turn on the water supply to the chlorinator, and also turns it off when the water pressure is shut off.

This scheme worked perfectly for about three winters and then a ground started to show on our switchboard. We traced it to the heater and found that in our zeal for efficiency and in our desire to utilize all the heat available we installed the heater with the electric connections pointing down. During the humid summer weather condensation from the outside of the pipe had run down on the electric connections finally causing the ground. We have now reversed the unit, putting the heater in from the top and expect no more trouble. We find that low heat, or 500 watts, is all the current we need to use except for a few days during the coldest part of the winter.



Our First Heater
(With Automatic Cut-off.)

This heating unit worked so well that we decided to put one on the chlorinator in our other station even though we use that station very little in the cold weather. This chlorinator was an older model and did not have a separate valve and line for the tray water supply, so we connected the heater similar to the other installation but conveyed the warm weather from the heater directly over the top and into the tray. The water supply was adjusted so that the water flowing through the heater and into the tray was just a little less than the required amount, the remainder being supplied in the usual way through the float valve in the tray supply line. Here are pictures of the original upside-down job and the trouble free improved job on the second chlorinator.

GRAVER TANK & MFG. CO., INC.

4809-14 TOD AVE., EAST CHICAGO, IND.

NEW YORK CATASAUQUA, PA. CHICAGO TULSA

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WATER SOFTENERS — FILTRATION SYSTEMS — CLARIFIERS — SEWAGE EQUIPMENT
STEEL STORAGE TANKS — VAPOR CONSERVATION EQUIPMENT — FABRICATED STEEL AND NON-CORROSIVE PLATE

PRESSURE FILTERS

Graver Pressure Filters, either vertical or horizontal type, built in any size to meet your individual requirements, consist of a pressure tank containing the filtering material and piping for delivering unfiltered water to the top of the bed and discharging the clear, filtered water from the bottom. Arrangement is made to reverse the flow at a rate sufficient to wash the filter bed, the rate of backwash being between 12 and 15 gallons per square foot of filter area per minute.

The thousands of Graver Pressure Filters in use today have demonstrated their exceptional efficiency as well as their low cost of operation and maintenance.

ZEOLITE WATER SOFTENERS

Graver Zeolite Water Softeners are the result of more than thirty years' experience in the design and manufacture of water conditioning equipment of all types. They provide an efficient, economical means of removing such impurities as calcium, magnesium, iron, manganese, etc., from water used for municipal, industrial, and institutional purposes. Their high efficiency, together with low operating and maintenance costs, are responsible for their widespread popularity.

HOT PROCESS WATER SOFTENERS

The Graver Hot Process Water Softener is designed to condition water used for the stationary boiler plant. It serves a dual purpose—it softens, heats and deaerates raw water make-up, and it heats and deaerates condensate returns.

The equipment is provided with individual chemical feeds and proportioners for the feeding of lime and soda ash for softening of the raw make-up water; sodium sulphate feeder for the correction of sulphate carbonate ratio in accordance with the A.S.M.E. code requirements; sodium sulphite feeding and proportioning equipment for removing the last trace of free oxygen from the water entering the boiler plant; and phosphate feeding equipment for the treating of water inside the boiler drum for removal of residual hardness remaining in the boiler water.

Equipment of this type covers every phase of treatment of both raw make-up water and condensate return, providing positive protection for boilers operating at extremely high pressures.

SWIMMING POOL EQUIPMENT

Broad experience in the water conditioning field has enabled Graver to develop complete swimming pool equipment to meet the most rigid requirements. The results obtained with Graver equipment in both indoor and outdoor pools prove that it is properly designed to produce the desired results efficiently and economically.

OTHER GRAVER PRODUCTS FOR THE CONDITIONING OF WATER AND TREATMENT OF SEWAGE

Aerators	Proportioning Equipment	Biological Filter Plants
Chemical Feeders	Digestors	Chemical Treatment Plants
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Chlorinators	Swimming Pool Equipment	Reactivator Clarifiers
Filters	Thickeners	Reactivator Softeners
Filtering Material	Vent Condensers	Zeolite Softeners
Heaters	Activated Sludge Plants	Hot Process Softeners

If you have a water conditioning or sewage treatment problem, consult Graver. There's no cost or obligation.

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"EMERGENCY CHEMICAL-FEEDER HEADQUARTERS"

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% Proportioneers % BLITZ BUGGY or Separate Units Are the Answer to Your Emergency Needs

New Bulletin EMM, available upon request, shows in detail the complete "Tailor-Made" Blitz Buggy designed with a complete assortment of sterilizing and pumping units for all emergency services. Many are detachable for use "on location" while trailer goes on to other danger points. The smaller model Blitz Buggy, suitable for smaller communities, is shown in Fig. 1.

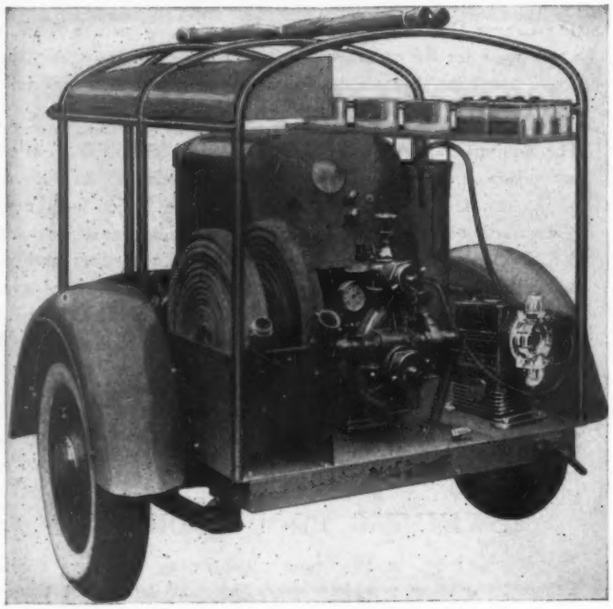


Fig. 1—Small "Tailor Made" Blitz Buggy

Bulletin EMM also describes individual units you can buy to make your own emergency truck or trailer outfit: Dual Drive (electric motor-gasoline engine) Portable unit (Fig. 2) which fits into trunk of car; Meter controlled Main Sterilizer; One-Man portable all-hydraulic Chlor-O-Feeder; or the complete Pur-O-Pumper unit as supplied to the armed forces for pumping, filtering, and sterilizing—a complete water supply for temporary service. Write for a copy of Bulletin EMM.

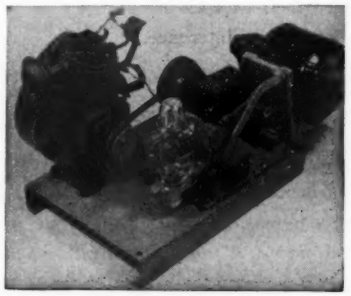


Fig. 2—Portable Chlor-O-Feeder

PRODUCTS — Single or Multiple Chemical Feeders for water and sewage plants, the military, and industry; and engineering service on proportioning problems. Feeders are of positive-displacement solution-feed type. For constant rate or proportional feed with mechanical or hydraulic operation. Chemical solutions handled with "See-Thru" transparent plastic reagent end construction include: Sodium or calcium hypo-chlorite, aqua ammonia, soda ash, alum, ferric chloride, ferric sulphate, calgon, sodium aluminate, copper sulphate, sodium hydroxide, dilute acids, etc. Other construction for concentrated Sulphuric acid and hard to handle chemica's. "Name your poison" and we will feed it!!

Chlor-O-Feeders in Water Works Service for Sterilization (Hypo-Chlorinators) — Midget Chlor-O-Feeders (diaphragm or piston type for low or high pressures) for pumped water supplies are the most dependable and least expensive, most accurate and least complicated feeders available for chlorination of up to 1½ million gallons per day. The Chlor-O-Feeder is small, easily and quickly adjustable to various feeding rates; driven by electric motors or belt driven from water pump. Installation is simple with aid of our complete instruction manual.

Proportional Chlor-O-Feeders for Gravity Water Systems — For many conditions, especially in gravity systems from reservoirs, where flow rates vary considerably from hour to hour, it is essential that the Chlor-O-Feeder be controlled by the flow of water so that the amount of solution injected is at all times in proportion. Proportional Chlor-O-Feeder can be mounted on and controlled by any flow-responsive device; standard water meter of any size or type; flow-responsive rotor; Venturi tube; orifice plate or even the reciprocating parts of deep-well pumps can be used to "pull the trigger" that sets off the chlorinating discharge. This Chlor-O-Feeder can be operated at any point where the water line can be cut to allow installation of meter. It can be operated entirely by water pressure, so does not require expense of wiring. Operation is simple, not needing expert attendants.

Calgon Feeding and pH Control—pH control by proportioning lime, soda ash, sodium silicate, sulphuric or other acids, is made simple by the use of these flow-proportional chemical feeders. Highly successful installations, designed by leading engineers, are providing permanent relief from plugged and corroded pipe lines. The growing use of Calgon in water works corrosion control finds frequent use of Calgon-Feeder for feeding sodium hexametaphosphate.

IRON REMOVAL—SMALL SYSTEMS

By H. E. LORDLEY, Plant Manager

Department of Public Utilities, Richmond, Virginia

IN THE country today we have excellent large water purification plants with competent engineers and operators, yet in number these plants represent only a very small percentage of our water supplies. Thousands of small supplies having only a deep-well-pump and storage tank challenge the water works engineer with problems that must be solved with limited expenditures and with unskilled operating personnel. Of the many problems, economical methods of iron removal are of major interest.

Forms of Iron

Iron may occur in water either as organic iron, inorganic iron or a combination of both types. Ferrous bicarbonate is one common inorganic form of iron occurring in many supplies. Iron in combination with humic acid or other complex organic compounds may be classified as organic iron, and is usually found in wells located in swampy areas. It requires only a few simple tests, that anyone can run, even without laboratory facilities, to determine the type iron. Collect a sample and allow it to stand exposed to the air. Inorganic iron will precipate, leaving the sample cloudy. On the other hand, organic iron fails to precipitate and the problem of removal is more complex thereby.

Methods of Removal

Methods of removal may be classified as (1) Direct Chemical Reaction, (2) Coagulation, (3) Special Filters.

Under No. 1 we have aeration as the most economical method. Aeration requires only 0.14 parts of air per part of iron when carbon dioxide is not present. The iron is oxidized to insoluble ferric iron which precipitates and settles to the bottom of a tank or is removed by a standard sand filter. Frequently, this small amount of air can be introduced by some form of air pump or "sniffer" attached to the well pump. (2) In an open system a tray aerator followed by sand filtration removes the iron. Organic iron is combined chemically so that such a simple treatment will not break down the organic bond.

The second method involving direct chemical reactions utilizes chlorine for the oxidation of the iron instead of aeration. In addition, the chlorine treatment removes any troublesome sulfuretted hydrogen often found in conjunction with iron, and produces a sterile water having a definite residual chlorine. This is a cheap method since solutions of "Perchloron" or "H.T.H." are convenient sources of chlorine and can be applied to small supplies without difficulty.

Causitc Soda removes iron from water by raising the pH to range 8.0-10.0. At the high pH the oxidized iron precepitates as ferric hydroxide and is removed by settling or filtration. This treatment also has the advantage of removing free carbon dioxide and protects the system from corrosion.

Potassium permanganate has been used (3) to oxidize organic iron by first attacking the organic compound and allowing the iron to precipitate as hydrous ferric oxide or a combination of ferric iron and organic matter.

In this discussion of direct chemical methods, none of these suggested methods removed organic iron with any degree of success so that we use the old standby, coagulation with alum. Organic iron occurs in a colloidal state with humic acid, cellulose, and other end products of plant decomposition. Alum coagulation followed by filtration will remove this form of iron.

Contact Beds

Special filters, the third classification, are excellent in many cases and are very easy to operate. These filters are standard pressure filters, having a material of the same general characteristics of filter sand but impregnated with the higher oxides of manganese (MnO; Mn_2O_7). Water supplied to the filter must have an oxygen content equal to 15% of the soluble iron content for the oxidation process. The iron in the presence of oxygen and by the catalytic action of the manganese, is converted to insoluble iron and is removed by the filtering material. In backwashing, the precipitated iron is washed out and the filter is ready for use without regeneration. Occasionally the sand is treated with sodium permanganate to aid the catalytic action of the manganese. Even these filters fail to remove organic iron in some cases and should be installed only after analyses and surveys indicate that such contact materials will remove the iron.

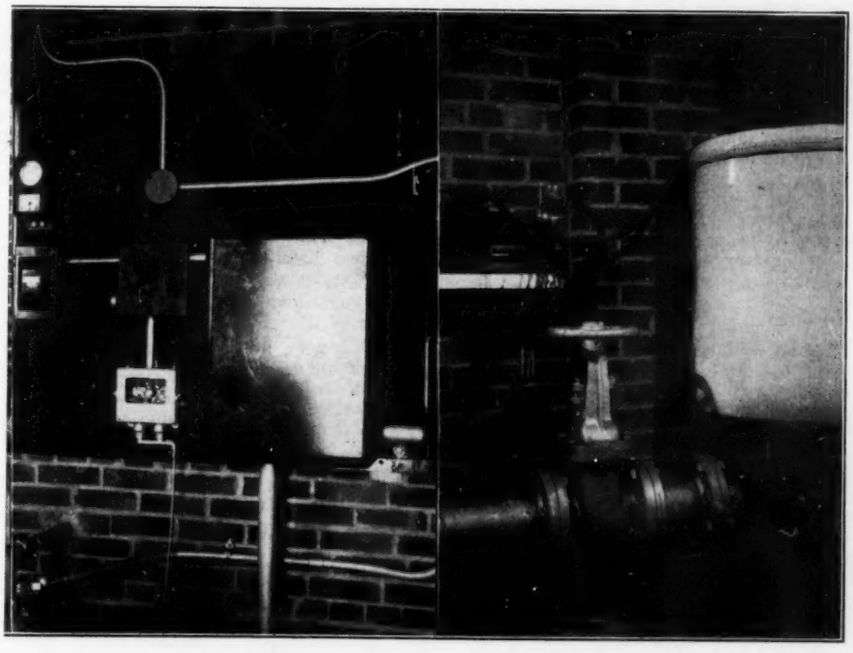
Ordinary sodium zeolite filters will remove iron by exchange as shown by the following reaction:

$$Na_2Z+MnO:Mn_2O_7+4Fe(HCO_3)_2=Na_2Z+3MnO_2+Fe_2O_3+8CO_2+4H_2O$$

There are some plants that use one set of two of these filters to soften the water and another similar set to remove iron and manganese. Many different materials have been used in filters, from pyrolusite to coal, and new materials are coming into use in this very promising approach to iron removal each year.

A Case at Point

With this introductory discussion as a basis, several plants designed by Mr. M. C. Smith and the author will illustrate the practical application of these methods. The City of Richmond operates a deep water freight terminal below the City which has a domestic water supply from a 280 foot drilled well. Shortly after opening the terminal the domestic water developed bad tastes and odors and also deposited an iron stain on all the fix-



Control Panel
Time Switch, Magnetic Starter and Pressure Switch.

Double Duty Chloro Feeder
With 40-gal. crock of caustic soda and hypochlorite solution.

tures. Samples direct from the well and from the distribution system had the following analysis:

Table 1.

	At Well	*From Mains*
pH	6.0	6.4
CO_2	41	31
M. O. Alk.	40	65
Color	6	27
Turb.	1.5	3.0
Fe	10.0	8.0
H_2S	Present	None

When the samples were first collected the water was clear but after standing a few hours it became cloudy and indicated inorganic iron. After a few jar tests this theory was proved by the ease of oxidation with any of the direct chemical methods. Finally a combination treatment using both chlorine and caustic soda was selected for the job for the following reasons:

(1) The treatment removed ferrous iron in a heavy floc without the expense of aeration.

(2) Eliminated carbon dioxide and prevented corrosion.

(3) Eliminated sulfuretted hydrogen.

(4) Sterilized the water and gave a residual chlorine.

(5) The two solutions could be mixed in the same crock and fed through one feeder.

Elevated Tank as Settling Basin

The City had appropriated only $500 for the job, so we were forced to use the elevated tank as a settling basin and purchase only a heavy-duty Proportioneer's feeder, 40 gallon crock, time switch and a few lengths of pipe. The 30,000 gallon storage tank was of conventional design with a short riser pipe within the 36" standpipe. This short riser-pipe was extended to about five feet above the bottom of the tank as shown in the accompanying sketch. Of course, this reduced the available water storage but furnished a settling basin in the bottom of the tank for the sludge, which settled so rapidly and completely that no filter was necessary.

In this system, as is true of other small supplies, little or no water was used after 9 p. m. so a time switch was adjusted to start both the pump and chemical feeder simultaneously at that time. This program also prevented untreated water from going into the system. A mercoid pressure switch in series with the time switch controlled the elevation of water in the tank. In this case the pump only operates a short time each night so the floc all settles before the draw comes on at 7 a. m., and gives a clear supernatant for consumption. About once a week the drain valve at the bottom of the standpipe is opened to remove the sludge from the tank.

The operating personnel could give the system only a weekly inspection and the chemical solutions were difficult to prepare in such a short time. However, in most cities some company manufactures liquid bleach and has a regular delivery system. In producing bleach 20% caustic soda is treated with chlorine to give a 15% available chlorine solution. In this case, the dealer delivered both 20% caustic soda and bleach direct to our 40 gallon crock. As the result the operators at the terminal did not have to prepare any solutions. In addition, the treatment was constant and the danger of inexperienced men handling chemicals was eliminated.

Results

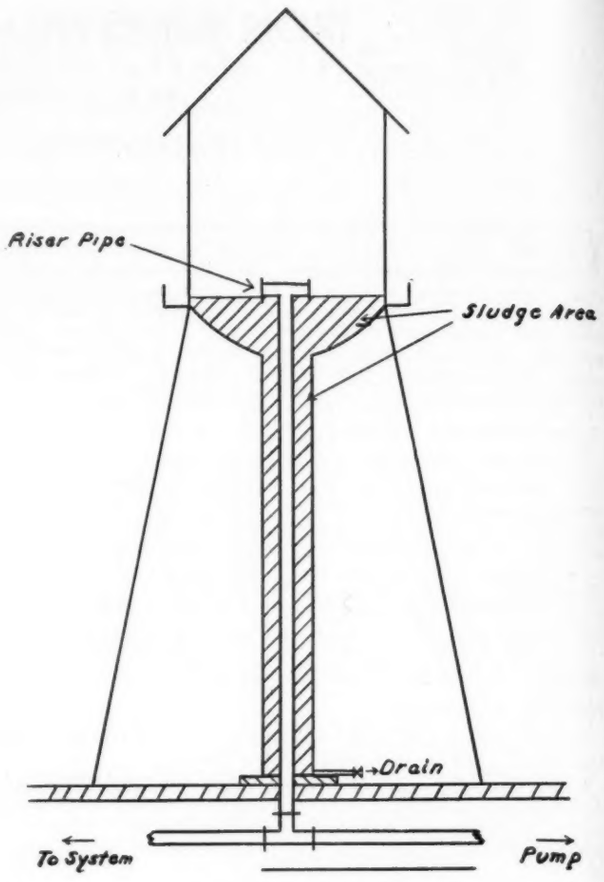
After a few adjustments and flushing of the system, the water was of excellent quality and could be used for all domestic purposes. Table 2 reveals the gratifying results with this treatment as evidenced by samples taken from the piping system.

Table 2

Dose. Caustic Soda 200 pmg. (100% NaOH) Chlorine 8.34 pmg.*

	(Before Treatment)	*(After Treatment)*
pH	6.4	9.0
CO_2	31	0
M. O. Alk.	65	110
Phenol. Alk.	0	7
Color	27	10
Turb.	3.2	0.60
Fe	10	0.01
H_2S	Present	None

*pmg. = pounds per million gallons.



Sketch of Converted Tank

Reveals simple changes made in extending the riser pipe and adding a tee to provide the shaded sludge separation zone. Accumulated but sterilized iron sludge is blown off systematically at the bottom of the original riser pipe.

Another Case

Never take iron for granted, for sometimes you realize that nature cares nothing for the theories of mankind.

Take for example a 284 ft. deep well only five miles from the above supply. Table 3 reveals the characteristics of its water.

Table 3
(Well No. 2)

pH	7.3
CO_2	9
M. O. Alk.	136
Color	28
Turb.	1.5
Fe	3.0
H_2S	Present

We expected this water to respond to the same treatment but after a series of jar tests we found that the iron was in the organic form and required an elaborate filter plant with chlorination, alum coagulation, settling, filtration and pH correction to give the same quality effluent as produced by the simple chlorination, alkalinization and settling plant. Only three miles from this supply another deep well needed only chlorination and settling in our special tank to give an excellent water, so you never know about the fallacies of water until an actual study is made of its amenability to a given treatment.

References

(1) Negus, Sidney S., "The Physiological Aspects of Mineral Salts in Public Water Supplies." J.A.W.W.A. 30:242 (Feb. 1938).

(2) Taylor, D. R., "That Air Sniffer." W.W. & S. 88:352 (August 1941. (Also page 74 of this Section.)

(3) McCrea, T. R., "Removal of Organic Bound Iron from Highly Colored Water." J.A.W.W.A. 25:931 (July 1933).

ENSLOW CONTINUOUS STABILITY INDICATOR

By ROBERT S. PHILLIPS, Chief Chemist
Water and Sewerage Department, Durham, North Carolina

OUR laboratory, like many another throughout the country, was extremely interested in the "Convention-Floor" invention of Linn H. Enslow, editor of WATER WORKS AND SEWERAGE, which has come to be known as the Enslow Continuous Stability Indicator or Enslow Stabilizer. This instrument, streamlining the so-called "Marble Test," seemed to be the answer to the water works operator's need for a practical short-cut to determine the proper treatment to attain the equilibrium point of finished waters. With certain modifications, explained later in this article, this instrument has been, and is, able to accomplish all its inventor originally hoped for.

Following publication[1] of early designs, we constructed a Stabilizer similar to that suggested. We soon discovered, however, that fine Calcium Carbonate did not behave according to our preconceived notions. Explained simply: if water velocities in the Stabilizer were high enough to suspend the chalk, fine Calcium Carbonate would carry over into the Stabilizer effluent, if velocities were low enough to obtain a clear effluent, "packing" and consequent short-circuiting of the chalk resulted.

The problem, therefore, was one of finding a closed device which could be added to the system and which would provide an adequate contact period with the fine calcium carbonate without sweeping over chalk. In other words, a container was needed which would provide for both high and low water velocities under constant flow conditions. A conical vessel, having a relatively small cross-sectional area at its vertex and a large area at its base, would solve the problem, it was thought, if the water was introduced at the vertex. This idea was based on the same principle as that of the Spaulding Precipitator, and was suggested by one of our Durham chemists, now Captain L. A. Lubow, U. S. Army. For experiment a separatory funnel of 500 mls. capacity was employed with success. Here the relative water velocities, base to vertex, were approximately 75 to 1. Later a two-liter cone-shaped device was made available by one of the laboratory supply houses. We have continued to use the two-liter cone since that time and have tentatively named it the "Contactor."**

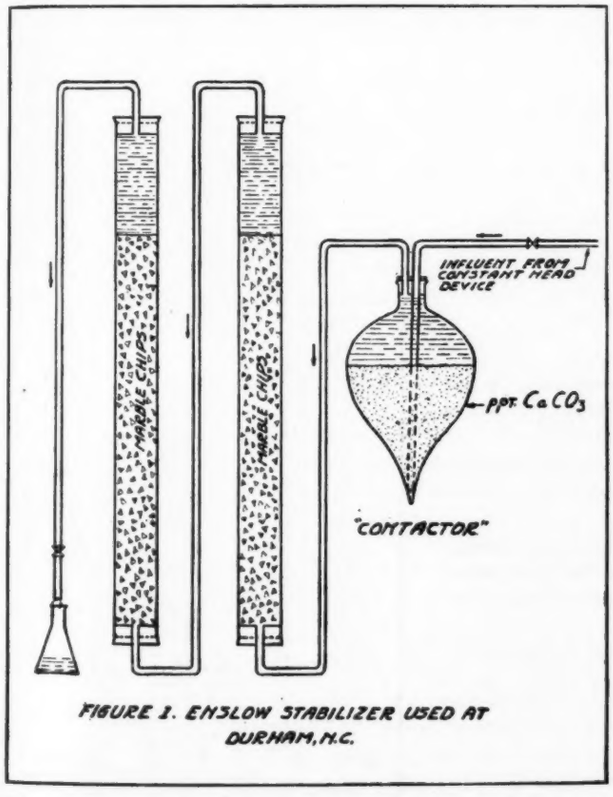


Fig. 1—The Original Enslow Stability Indicator to Which the Durham "Contactor" Has Been Added

The "Contactor" provides intimate contact with fine precipitated chalk; high velocities at the vertex cause a moderate expansion of the entire mass of chalk, allowing the water in its upward travel, under decreasing velocity to "filter-through"; and the effluent from the "contactor" is substantially clarified, leaving only a small amount of fine material to be filtered or plated out by the coarse marble chips later. See Fig. 1.

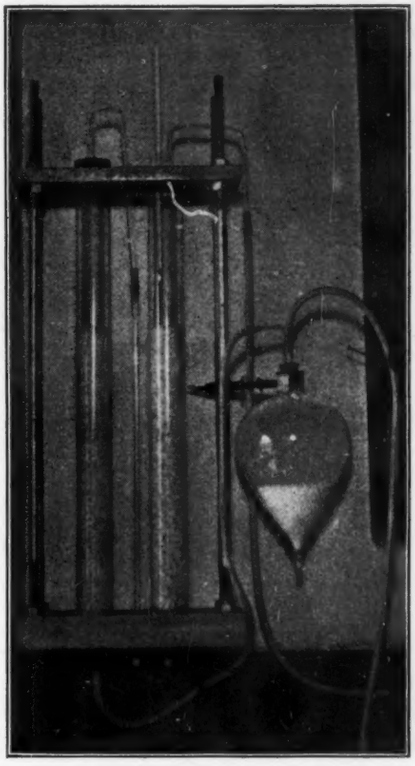


Fig. 2—The Improved Enslow Stability Indicator in Service

Results of Operation

Our Continuous Stability Indicator with the above modification has been in operation since February, 1940. During that period daily samples have been taken at two widely separated points on the distribution system, and compared analytically with samples from the Stabilizer and with the finished water pumped from the treatment plant. One point of sampling is our open elevated storage reservoir, where treated water is retained for an average of one week. The other is at an extreme end of the distribution system, where water use is relatively small. Admittedly these two points represent conditions at which sustained stabilization is most difficult.

Table No. 1 shows the results of a year and a half operation and the average monthly figures in both alkalinity and pH of the water at various points. The figures on total alkalinity indicate that the water was in equilibrium and that it did not tend to dissolve or deposit calcium carbonate. In other words, within the limit of accuracy of tests, the water was well-stabilized when treated according to indications given by the Enslow Stability Indicator.

It will be noted that the pH of the Stabilizer effluent is lower than that of the treated or tap water, although the alkalinity will be the same. This is believed to be due to the fact that small amounts of gases, such as CO_2, are dissolved in Stabilizer effluent while dripping into the container. For this reason, we disregard the pH readings on the Stabilizer effluent and treat, instead, to maintain a final treated water alkalinity equal to that shown by the Stabilizer effluent.

Enslow Index vs. Langlier Index

Since 1937 we have been determining the Saturation Index by the Langlier Formula[2]. For comparative purposes I have included a column labeled "Langlier pHs," which is a monthly average of the Langlier pH of saturation. It indicates that on an average the pH of saturation indicated by the Stabilizer is somewhat lower than that calculated by Langlier formula.

In the early fall of 1940 an interesting change took place which illustrates the practicability of the Continuous Stability

**Phipps and Bird, Inc., Richmond, Virginia, now manufactures an Enslow Stabilizer which includes the Durham "Contactor."

Indicator. We had been taking untreated water from one source which was practically identical in characteristics to that of another source. The only apparent difference was one of carbon-dioxide content and a depressed pH. A change was made from one source to the other. No alteration in coagulant dosages was required, yet the following changes occurred in the Stabilizer Effluent overnight.

	Raw Water No. 1	Raw Water No. 2
Date	9-23-40	9-24-40
Turbidity, ppm.	70	65
Alkalinity, ppm.	15	14
Free CO_2, ppm.	13	6
pH	6.2	6.7
Stabilizer Eff. pH	8.2	8.8
Stabilizer Eff. Alkalinity, ppm.	29	21

It must be admitted that considerable changes of this magnitude could not have been foreseen or predicted by any other simple method.

Some Notes on Operation

The total water capacity of the Stabilizer used at Durham is 3230 mls. exclusive of the volume occupied by the chalk and marble chips. The capacity of each part individually is as follows:

	Mls.
"Contactor"	2050
Twin tubes filled with marble chips (590 mls. ea.)	1180
Total capacity	3230

Each of the twin tubes contains about two and one-half pounds of marble chips. The "Contactor" contains approximately 200 gms. precipitated calcium carbonate. The latter is introduced into the "Contactor" mixed with 500 mls. water. The cone is filled completely with additional water and the mass allowed to settle thoroughly before placing into operation.

The normal operating rate is 25-35 mls. per minute, resulting in a contact period of approximately two hours. The "Contactor" alone provides nearly two-thirds of the total time. It is very important that the rate shall not ever materially exceed the upper limit, otherwise the purpose of the "Contactor" will be defeated by carrying over fine calcium carbonate into the effluent. A slower rate is satisfactory and for some waters the longer contact period may prove an advantage.

TABLE NO. 1

MONTHLY AVERAGES

	pH					Alkalinity as $CaCO_3$ ppm.			
1940	Enslow Stabilizer pHs	Langlier pHs	Tap	Reservoir	End Distribution System	Enslow Stabilizer Eff.	Tap	Reservoir	End Distribution System
March	9.0	9.0	9.1	9.0	8.6	20	21	20	21
April	9.1	8.9	9.1	9.1	9.0	23	24	23	24
May	8.7	9.0	8.8	8.9	8.8	25	24	25	25
June	8.4	8.8	8.6	8.6	8.5	23	23	23	24
July	8.4	8.9	8.6	8.5	8.5	25	23	23	22
August	8.3	8.8	8.5	8.4	8.5	27	27	26	28
September	8.5	8.8	8.7	8.5	8.5	24	25	24	25
October	8.7	9.0	9.0	8.7	8.8	24	25	24	24
November	8.8	8.9	9.0	8.9	8.9	25	25	27	25
December	8.9	9.0	9.1	9.1	a.	20	21	22	a.
1941									
January	9.1	9.0	9.1	9.1	8.9	23	23	23	22
February	9.0	9.0	9.1	9.1	9.1	21	22	22	23
March	9.0	9.0	9.1	9.0	9.1	21	21	22	23
April	9.0	9.0	9.1	9.1	9.0	22	21	22	23
May	8.9	8.9	9.1	9.0	9.0	23	25	24	25
June	8.6	8.9	8.8	8.8	8.7	26	27	26	28
July	8.5	8.8	8.6	8.6	8.6	27	28	27	29
August	8.4	8.7	8.5	8.5	8.5	33	33	33	32
Average	8.74	8.91	8.88	8.83	8.76	24.0	24.3	24.2	24.8

a. No samples taken.

It is advisable to mount the Stabilizer in a place out of direct sunlight to avoid the possibility of microscopic growths.

Occasionally it will be found desirable to clean the entire system and introduce new calcium carbonate into the "Contactor." A dilute solution of Hydrochloric Acid followed immediately by a thorough rinsing with water seems to accomplish the desired result quickly and efficiently.

After placing the Indicator in operation it will be found that some of the extremely fine (almost colloidal) chalk will be swept over for the first day or two. After this the effluent clears entirely, the colloidized chalk, if any, plating out on the marble chips.

References

1. "The Continuous Stability Indicator," Linn H. Enslow, *Water Works and Sewerage*, 86:107 (1939).

2. "The Analytical Control of Anti-Corrosion Water Treatment." W. F. Langlier, *Journal A.W.W.A.* 28:1500 (1936).

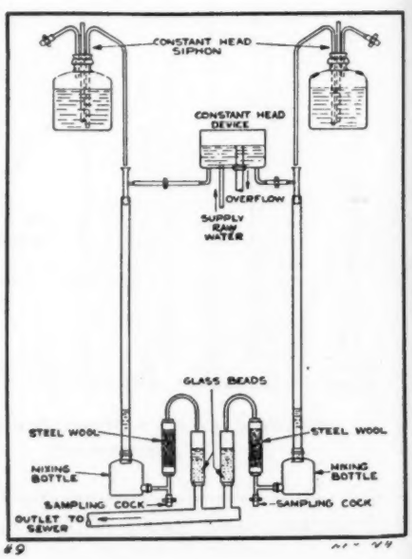
CORROSIVITY INDICATOR

THE accompanying sketch pictures a very effective piece of equipment devised and employed by Hall Laboratores, Inc., to study and demonstrate the efficacy of various treatments applied to waters for corrosion or scaling control.

The scheme involves passage of the water under treatment, for comparison, upwards through clean, bright steel-wool. The effluents leaving the wool contact chamber drips through clean glass beads.

The rapidity and relative intensity with which the steel rusts and the beads become iron-stained constitute a convincing semi-quantitative index of corrosivity. For greater exactness in comparison samples of effluent from the steel corrosive chamber are analyzed for iron, oxygen, etc.

It is evident that this apparatus can be employed with lead wool, copper-sponge, etc., to study action on these and other materials. A battery of as many units as required may be set up. The device has considerable resemblance to the Enslow Carboneous Stability Indicator.



OMEGA MACHINE CO.

3409 E. 18th St., Kansas City, Mo.

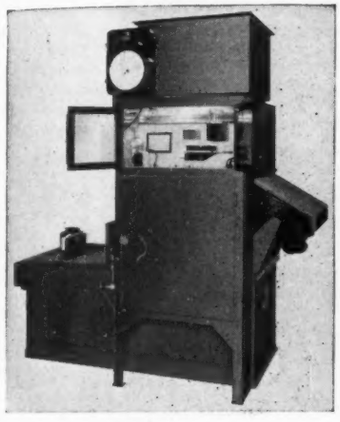
REPRESENTATIVES

Atlanta, Ga.—W. D. Taulman, 175 Spring St., S. W.
Detroit, Mich.—Wm. A. DaLee, Inc., 4835 Woodward
Hawaii—Alan Duvall, Box 33, Honolulu
Los Angeles—Chas. P. Crowley, 609 S. Anderson
Louisville, Ky.—R. M. Overstreet, 1317 S. 4th St.
New York City—Triangle Equipment Co., 50 Church St.
Philadelphia, Pa.—Alan A. Wood, 2045 N. Broad St.
Toronto, Ontario—Control & Metering, 454 King St. West
Brazil—Oscar Taves & Co., Box 840, Rio de Janeiro
Colombia—MacDonald & Peterson, Ltd., 502 Banco de la Republica, Bagota.
Argentine—Fiore Co.—Pasco Salon 285—Buenos Aires

EQUIPMENT

For Dry Material	*For Liquids*
Batch type Gravimetric Feeders	Precision Feeders
Belt type Gravimetric Feeders	Rotodip Feeders
Weighcheck Feeders	Proportioning Pumps
Universal Volumetric Feeders	Laboratory Stirrers
Lo-Head Feeders	Lime Slakers
Disk Feeders	High Speed Agitators
Dust Removers and Filters	Slow Speed Agitators
Combined Bucket Elevators & Feeders	Automatic Proportional Control

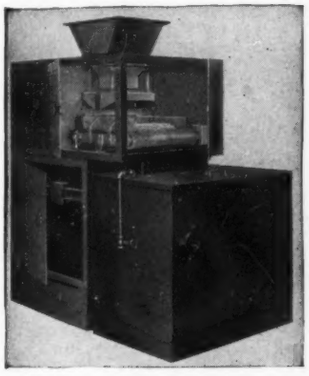
GRAVIMETRIC FEEDER AND SLAKER



A size No. 1 Gravimetric Feeder with 2,000 lb. hopper and mechanical operation recorder is illustrated mounted over a Lime Slaker. Slaker sizes range from 175 lbs. to 6,000 lbs. per hour.

In this type Gravimetric Feeder the entire hopper load of chemical is carried on the scales which control the rate of feed. Errors cannot be cumulative.

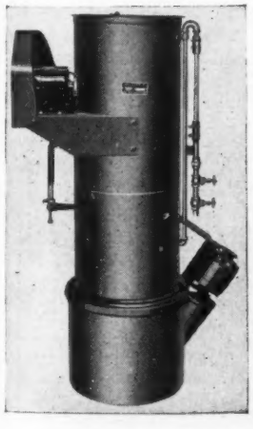
BELT TYPE GRAVIMETRIC FEEDER



Weighs the material as it is fed on a short section of conveyor belt which is mounted on accurate scales. These feeders may be connected directly to large overhead storage bins if desired.

Accurate feeding range is from 5 lbs. to 3,000 lbs. per hour. A totalizer shows the number of pounds of material that have passed through the feeder.

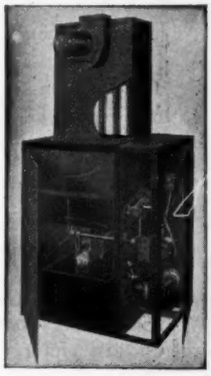
UNIVERSAL FEEDER



Rugged, accurate Volumetric Feeders. Designed to be used with extension hoppers or with overhead storage bins.

The No. 3 size Universal Feeder illustrated has a lead lined mixing chamber and motor driven, stainless steel agitator for dissolving Ferrisul. The water supply to the mixing chamber is measured by a Rotometer. Separate valves are used to regulate and to shut off the water supply.

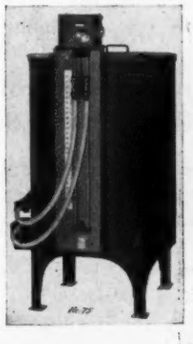
LO-HEAD FEEDER



Large hopper capacity with only 45" filling height. Rates of feed from 1 to 200 lbs. per hour. Cabinet type illustrated with feeding and driving mechanisms completely enclosed in separate compartments.

Any Omega feeder may be equipped with the dust remover and filter illustrated. The filter may be connected to several machines to remove dust incident to filling the hoppers with carbon, lime, etc.

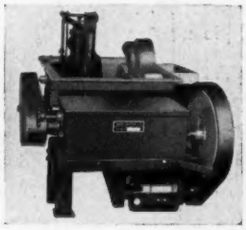
PRECISION FEEDER



The most accurate and simplest type of feeder for solutions or light suspensions. Rate of feed is set by a dial to desired percentage of maximum rate. Feeding capacities range from 1/25 to 400 gallons per hour. Electric or spring motor drive.

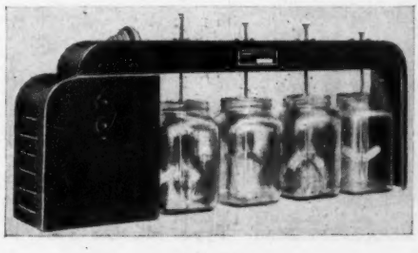
Tanks may be equipped with dissolving baskets and agitators for dissolving lump material. Tank sizes 25 to 400 gallons.

ROTODIP METER



For feeding from large supply tanks which may be located at a distance from the feeder. Feeding range 1 to 800 gallons per hour. Galvanized, rubber covered or plain steel construction. Variable speed drive gives an infinite number of speed changes from zero to maximum rate.

LABORATORY STIRRER



For jar tests, to determine proper coagulant or carbon dosages. Also ball mill or tumbler type for agitating material in closed vessels, for threshold treatment tests.

WILSON CHEMICAL FEEDERS, INC.

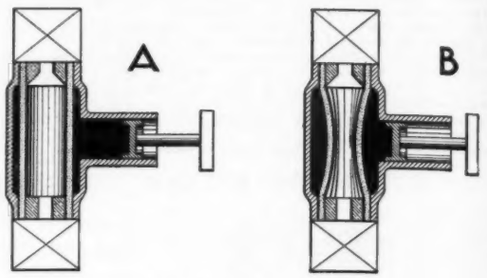
Manufacturers of PULSAFEEDERS for Hypo-Chlorination of Water
BUFFALO, NEW YORK

HOW PULSAFEEDER WORKS

The extreme simplicity of operation of the PULSAFEEDER is illustrated at the right.

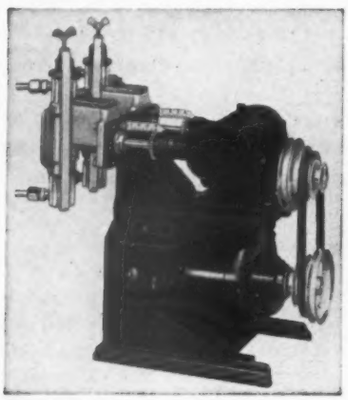
The re-agent head primarily consists of a piston operating in a chamber which contains a flexible diaphragm, completely surrounded by an inert liquid. As the piston travels forward in the chamber the liquid causes the diaphragm to change shape, as is shown in Drawing "B". The diaphragm completely houses or isolates the chemical solution being pumped, and therefore there is no contact with moving or operating parts. Inasmuch as equal pressures exist throughout, there is no possibility of rupture. Preforming or reinforcement of the diaphragm is unnecessary. Reciprocation of the piston causes pumpage of the chemical solution.

Volume control is provided by a micrometric stroke length control, the average size PULSAFEEDER having over one thousand settings with an increment of adjustment of .0277 of a millimeter. Sizes range in capacity from a minimum of 1 cc to 360 gal. per hour.



Patent Applied For

TYPE DES



TYPE DED

TYPES DET, DEQ

Types of "PULSAFEEDERS"

The various types use electric motor, gasoline engine, water or air motor drives, and are controlled by water meters of all types. Semi-automatic, manually adjustable, and fully automatic hypo-chlorinators are available. Single, duplex, triplex and quadruplex manually controlled feeders are pictured at the left; fully automatics, as shown at the right, can be had in multi-feeders for two or more chemical solutions. There is a PULSAFEEDER to give perfect results, whether the installation is a gravity water supply, pumped supply or a swimming pool.

Manually Controlled "PULSAFEEDERS"

Type DES: For use with pumped water supplies. Automatic proportioner when cross-connected to throw-out switch of water pump. Bulletin DE-201.

Type DBS: Same as DES arranged for belt drive. Bulletin DB-16.

Type DED: Duplex feeder similar to DES, ordinarily used with ammonia and chlorine solutions for chloramination. Each pump separately adjustable. Bulletin DE-202.

Type DET (Triplex), DEQ (Quadruplex): All purpose swimming pool chemical feeder. Feeds chlorine, the sterilizer; alum, the coagulant; soda ash, the pH adjuster, and ammonia for chloramination. Each unit separately adjustable. Bulletin DE-203.

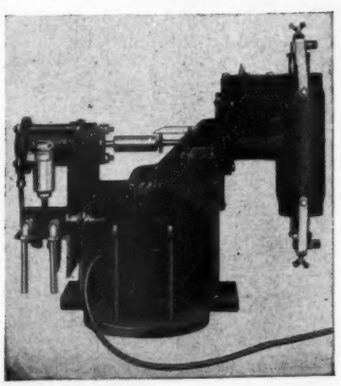
Automatic "PULSAFEEDERS"

Type MC-DS: Fully automatic hypo-chlorinator for gravity water supplies. Water motor powered and meter controlled. Guaranteed as accurate as the meter. Bulletin MC-20.

Type MC-DES: Fully automatic proportioning type. Electric motor drive and control by any mechanical water meter. Bulletin DE-206.

Type MC-DS-SM: For automatic or semi-automatic use. Water motor drive. Bulletin DE-204.

TYPE MC-DS



TYPE MC-DS-SM

CHLORINATION EQUIPMENT FOR EMERGENCY USE

By HARRY A. FABER, Research Chemist
The Chlorine Institute, Inc., New York, N. Y.

THE purpose of this paper is to provide specific information regarding material and equipment which is available for or which may be adapted to emergency chlorination of water supplies.

Normal treatment and distribution of a safe water supply is subject to interruption by acts of nature or of man. It has been pointed out (1) that because a public water supply is essential both for domestic needs and for fire fighting, water department authorities have a definite responsibility to provide equipment which will insure the minimum interruption of water service.

During the past few years, experience has demonstrated not only the necessity of continual vigilance under normal conditions of operation but the necessity of being prepared to meet abnormal conditions of operation. Chlorination is recognized as a necessary factor of safety in the normal treatment of water supplies. It is equally essential that provision be made in time of emergency to insure the delivery of water disinfected by chlorination.

The experience of those who already have gained familiarity with this problem provides the best basis for development of any new program. Descriptions of those procedures demonstrated to be effective warrant careful study. Papers by Arnold[2] and by Devendorf[3] report a variety of experiences with emergency chlorination measures. These were adopted to treat public water supplies contaminated under conditions of normal operation. Papers by Gledhill and McCaulis[4] and by MacKenzie[5] describe the development of successful disinfection procedures for combating pollution resulting from fracture of water mains by high explosive bombs.

In order to perfect a clear plan of action, it is necessary to determine the requirements of each supply and each situation. Experience shows this can best be accomplished by providing three essentials: The man, the material, and the machine.

The Man

Prompt and effective emergency chlorination can be no better than the personnel which has been made responsible for the job. General rules of procedure cannot be laid down for all muncipalities, or all supplies, or all emergencies. Rather, the plan developed must be based on the conditions which obtain in each locality.

Authority should be delegated to a competent member of every water supply organization to survey the local situation. His survey should include a study of each potential weakness in the normal operation of water chlorination. This is no time to place dependence upon inadequate or obsolete chlorinating equipment. This is no time to lack duplicate chlorinating units or spare parts necessary to uninterrupted operation. This is no time to lack the protection of secondary chlorination at points where reconatmination is possible; at storage reservoirs, floating reservoirs, and distribution reservoirs.

Under abnormal conditions a water department may find itself called upon to supply much more than the normal quantity of water, either because of wastage from broken mains or in order that fire fighting can be carried on effectively. Chlorinating equipment must be ample in capacity to disinfect increased volumes of water required by these causes.

Under emergency conditions, special portable or mobile units may be required either to disinfect contaminated sections of a distribution system or to treat a separate emergency supply. The survey should consider each of these contingencies because, while abnormal, they are certainly potential occurrences.

When this survey is completed it will reveal the strength and weakness of the local situation; where chlorination is necessary, where it is provided, and where additional or emergency chlorination may be required. This survey, however, represents only the recognition of the situation.

The second step, therefore, is to provide the indicated total protection to the best possible degree. In the case of a small water system, only minor provisions may be required, while in the case of an extensive system many weaknesses may require correction. There will probably be no better time than the present to secure funds for providing new equipment.

Finally, a detailed plan of procedure should be worked out and put in written form. Each chlorinating unit and each point of chlorine application is a point of potential disinfection falure; therefore, the detailed plan should indicate as simply as possible exactly what procedure is to be followed in the event of such failure. If a duplicate unit is to be substituted, if an emergency unit is to be provided, if the chlorine dose is to be increased elsewhere, that instruction should be clearly stated.

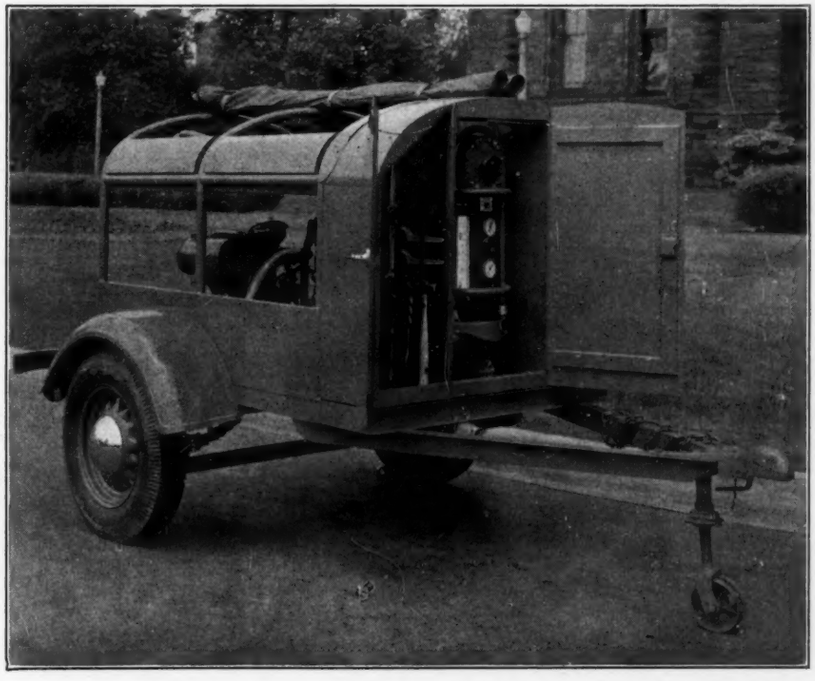
The individual who has studied the entire situation and who has drawn up the detailed plan of procedure, would then be the logical man to whom full authority should be delegated. Only when complete responsibility is given to one individual will prompt and decisive action be forthcoming. This is necessary also because the chlorination authority must co-operate with those responsible for other phases of emergency procedure. The program of emergency chlorination must be integrated with the entire program of plant operation, distribution system repair, and emergency sources of supply.

Such a precautionary program is applicable, irrespective of the size or number of employees of the water system. Only when one individual is given responsibility and adequate precautionary measures have been provided can criticism be forestalled, excessive emergency expenses be prevented, and the well-meaning but often dangerous efforts of incompetent individuals or organizations be discouraged.

The Material

Liquid Chlorine

The assured availability of liquid chlorine for disinfection of water supplies has been reviewed (6). In the event of emer-



Wallace & Tiernan's Newest Mobile Emergency and Utility Chlorinating Unit Carries two cylinders of chlorine and gasoline engine driven injector water pump, all necessary tools and especially designed chlorinator of high flexibility.

This paper, presented at the Toronto Convention of the A.W.W.A., in 1941, is here reproduced by permission of the Association.

gency, it is not probable that large additional amounts of chlorine will be required; instead, different points of application would be utilized.

However, the proposed plan of emergency procedure should include a survey of listing of emergency sources of chlorine supply. Nearby sewage treatment plants, swimming pools, laundries, or industrial plants should be contacted, and the potential emergency supply of liquid chlorine available from such sources should be determined.

Hypochlorites

Many small water treatment plants regularly use calcium hypochlorite for disinfection. This chlorine compound provides an excellent source of emergency chlorine for even the largest plants. The modern calcium hypochlorites contain 70% available chlorine, and are generally supplied in drums containing 100 pounds and in cans containing 5 pounds of the dry material.

Two such hypochlorites are available in the United States: "HTH," manufactured by the Matheison Alkali Works, and "Perchloron," manufactured by the Pennsylvania Salt Mfg. Co. In Canada there is one such hypochlorite: "Maxoclor," manufactured by Canadian Industries, Ltd. Each producer has available a booklet which provides useful information on the preparation and feeding of hypochlorite solutions.

This material may also be available through local distributors who supply laundries, industrial users, swimming pools, and other consumers. Each of these sources should be surveyed as a potential source of supply when facilities are provided to feed hypochlorites.

These hypochlorites are stable over a long period of time, if stored in a cool dry location. When dissolved in water the resulting hypochlorite solutions are corrosive to common materials, hence suitable equipment must be available to feed these solutions.

Other Chlorine Compounds

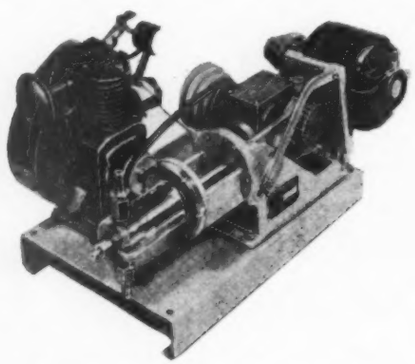
So-called "bleaching powder" or "chloride of lime" is available from local distributors in many localities. This material generally contains about 35% of available chlorine when fresh, but is not stable over a long period of time. Local sources should be investigated, however, if emergency equipment for feeding hypochlorite solutions is provided. Limited amounts of this material may also be found in drug, grocery, hardware, or poultry supply stores in one pound cans.

Sodium hypochlorite solution, usually containing about 15% of available chlorine, is obtainable through local jobbers in some localities. This solution may be purchased in 5 gallon carboys. Frequently small producers of household bleaching solution used this material, or make it from caustic soda and liquid chlorine, and market it under a wide variety of trade names in grocery stores. As sold, the household solution is usually very dilute, ranging from 3% to 5% available chlorine. It might be used in an emergency to provide very small amounts of chlorine.

The Machine

Chlorinators

Standard chlorinating apparatus is not an unusually heavy piece of equipment. The units regularly employed in water purification may be readily transported in emergency to various points of need.



Proportioneers' Hypochlorite Feeder
Designed for general utility and emergency use this model of "Chlor-O-Feeder" is equipped for electric drive (1/6th H.P. motor) and engine drive (½ H.P.)

The Wilson "Pulsafeeder"
This pumping type feeder employs the principle of hydraulic "squeezing" of the elastic pulsating tube passing through the compression chamber seen at upper right. The piston stroke determines the degree of the tube squeeze and feed rate, up to 75 gals. per hour for this particular model.

Chlorinator manufacturers are best able to designate the type of equipment most suitable for particular uses. There are two manufacturers of chlorinators: Wallace and Tiernan Co, Newark, N. J., and Everson Manufacturing Co., Chicago, Ill. They offer standard chlorinators suitable for various types of installations and for a wide range of dosage requirements.

Wallace and Tiernan Co. is experienced in the design and construction of mobile chlorinating units, using standard vacuum chlorinators, and has assisted in the design of other such units which were assembled and mounted by the customers. This company offers a stock model portable chlorinator, suitable for either direct or solution feed, which is especially applicable for main sterilization. The outfit is mounted in two compact cabinets, and is adaptable to a variety of uses. In addition, a new mobile trailer unit has been designed, completely equipped with a chlorinator, two cylinders of chlorine, and a self-powered pump. One of the newest of these units was on exhibition at the Toronto Convention of A.W.W.A. and is here pictured. It is a unit of considerable flexibility and its range of capacity is large.

Pumps for Feeding Hypochlorite Solution

Small pumps, which operate on a variety of principles, are available to feed hypochlorite solutions for disinfection. They are constructed of resistant material and have proven thoroughly satisfactory in service. Again in this case, the manufacturers will be most competent in designating the type of equipment best suited to each purpose. The units are suitable for continuous, emergency, or special chlorinating purposes and may be either manually controlled, operate automatically at a fixed dose, or provide a dose directly proportional to water flow.

The two types of this equipment best known in the water treatment field are those manufactured by Proportioneers, Inc., and by Wallace and Tiernan Co.

Proportioneers, Inc., Providence, R. I., offers a wide variety of such pumps under the name of "Chlor-O-Feeders." These range in capacity from 85 to 240 gallons per day maximum delivery. They operate by electric power, belt drive, waterpower, compressed air, or by power from a gasoline engine. In addition, duplex, triplex, and combinations up to 5 units can be provided with a capacity of 180 gallons per day for each pump. In addition, this firm also manufactures the "Pur-O-Pumper" unit, consisting of pump, filter, and hypochlorite feeder. It is powered with a gasoline engine, and therefore is a self-contained unit for producing filtered and chlorinated water.

Wallace and Tiernan Co., Inc., Newark, N. J., offers several models of a hypochlorite pump feeding a maximum of 60 gallons per day. These "Hypochlorinators" operate by electric power, belt drive, water power, or by power from a gasoline engine. Duplex pumping units are also provided in this equipment. Self-contained units, consisting of pump and hypochlorinator or of pump, filter, and hypochlorinator, are also available.

Other manufacturers offering a more limited variety of hypochlorite pumping units are:

Omega Machine Co., Kansas City, Mo. One model, electric or water power, 400 g.p.d. maximum capacity.

Everson Manufacturing Co., Chicago, Ill. One model, electric power, 24 g.p.d. maximum capacity.

Milton Roy Pumps, Philadelphia, Pa. Simplex model, electric power, 432 g.p.d. maximum capacity; duplex model 864 g.p.d. maximum capacity.

Wilson Chemical Feeders, Inc., Buffalo, N. Y. Five models of "Pulsafeeders" operated on electric or water power, standard capacity 96 g.p.d., and others.

The Hills-McCanna Co. of Chicago also produce pump type chemical feeders, especially suitable for injecting solutions against high pressures.

Hypochlorite Feeders Other Than Pumps

Omega Machine Co., Kansas City, Mo., offers a "Precision" feeder to deliver hypochlorite solution against zero back pressure or to a pump suction. This device consists of a solution tank from which the discharge rate is controlled by electric motor, spring operated clock drive, water motor, or by any reciprocating or rotating shaft. Maximum capacity is given as 192 g.p.d.

Phipps and Bird, Inc., Richmond, Va., offers a hypochlorite solution feeder, operating by either gravity or electric power, to deliver against back pressures of zero or up to 60 pounds. Maximum capacity is given as 45 g.p.d.

C. W. Sirch, Los Angeles, Calif., offers a "Paradox" feeder for hypochlorite solution, which operates by pressure differential between two points in the water main. Discharge rate is over a large range.

Home Made Hypochlorite Feeders

For temporary application of hypochlorite solution under emergency conditions, a variety of other feeding devices can be pressed into service. They should, however, be considered for temporary use only.

In emergency, any dry feed machine may be used to feed dry hypochlorites into a solution box, and the solution may be discharged by gravity or pumped to the required point of application. Only the 70 per cent calcium hypochlorite can be fed in such manner. Even this material is slightly hygroscopic and corrosive upon exposure to moist atmospheres; therefore, dry feed application must be limited to short periods of use only when no other equipment can be provided.

Several types of gravity or pump suction feeders can be made to serve during an emergency when no standard solution feed device can be provided, though their accuracy and dependability can never compare with equipment designed for this purpose. Hypochlorite solutions are corrosive to common metals, and parts used must be of suitably resistant materails such as glass, wood, rubber hose, hard rubber fittings, etc.

Hypochlorite solutions can be applied against pressure by using an injector. The pressure differential between the injector feed and discharge should preferably be 5 to 1 and must be at least 3 to 1 in order to obtain satisfactory operation.

Residual Chlorine Testing Equipment

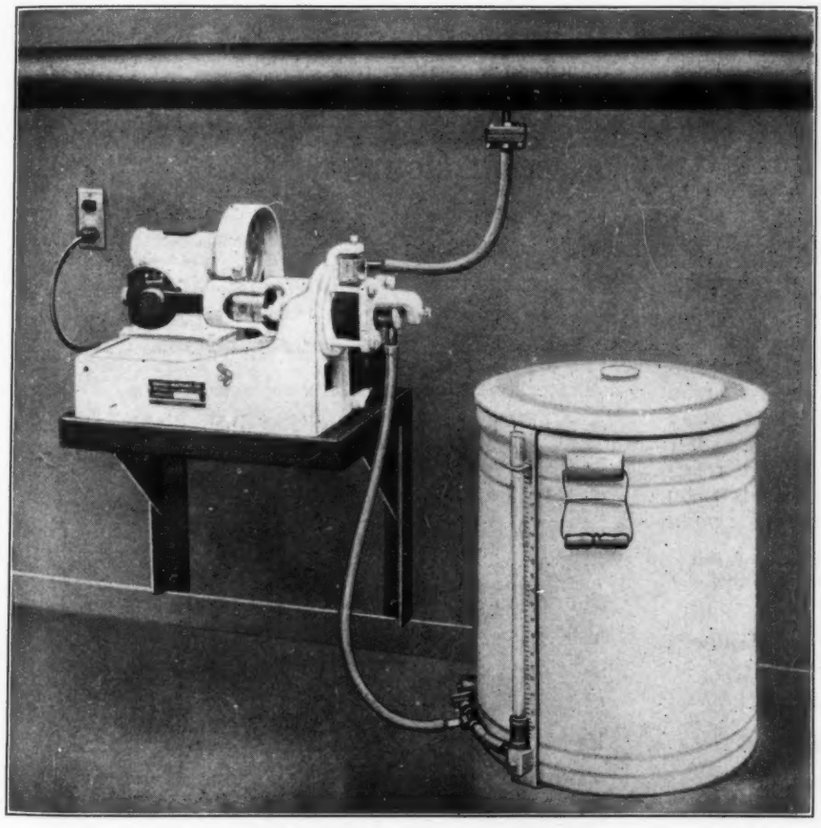
Proper control of chlorine dosage will usually be dependent upon the maintenance of a desired chlorine residual. Testing outfits are available both for the residual range covered in ordinary disinfection and for that which may be necessary in emergency chlorination.

For chlorine residuals of 0.1 p.p.m. to 1.0 p.p.m., outfits are offered by: La Motte Chemical Products Co., Baltimore, Md.; Proportioneers, Inc., Providence, R. I.; Rascher & Betzold, Inc., Chicago, Ill., and W. A. Taylor & Co., Inc., Baltimore, Md.

For chlorine residuals of 0.1 p.p.m. to 2.0 p.p.m., outfits are offered by: Hellige, Inc., Long Island City, N. Y., and by Wallace & Tiernan, Inc., Newark, N. J.

For chlorine residuals of 0.2 p.p.m. to 8.0 p.p.m., an outfit is offered by W. A. Taylor & Co., Inc, Baltimore, Md.

For higher chlorine residuals, outfits ordinarily used in testing bleaching or sterilizing solutions are offered by: Diversey Corp., Chicago, Ill. (100 p.p.m. maximum); Hellige, Inc., Long Island City, N. Y. (250 p.p.m. maximum); La Motte Chemical Products Co., Baltimore, Md. (100 p.p.m. maximum); The Mathieson Alkali Works, Inc., New York, N. Y. (220 p.p.m. maximum); Rascher & Betzold, Inc., Chicago, Ill. (220 p.p.m. maximum); W. A. Taylor & Co., Inc, Baltimore, Md. (250 p.p.m. maximum).



The Omega Hypochlorite Feeder
Pictured installed on standard wall bracket. The 15 gallon stoneware solution crock is equipped with a liquid metering gauge.

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6. Parran, Stettinius, et al. Exchange of Correspondence. Following page 1306. Jour. A.W.W.A., 33:7 (1941). Also, "Water Works and Sewerage," page 310, July, 1941.

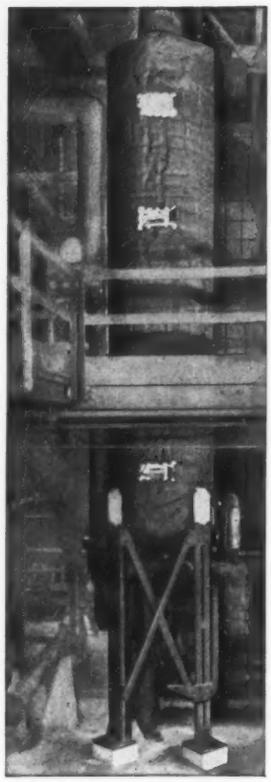
PENNSYLVANIA SALT MANUFACTURING COMPANY

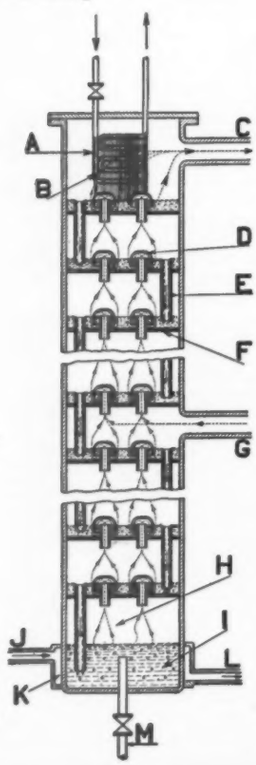
1047 WIDENER BUILDING, PHILADELPHIA, PA.

NEW YORK • CHICAGO • ST. LOUIS • PITTSBURGH • WYANDOTTE • TACOMA

• LIQUID CHLORINE

A clean amber - colored liquid about one and one-half times as heavy as water. Supplied in steel containers which are under pressure at temperatures above 30.1° F. It is only slightly soluble in water, its maximum solubility in distilled water being about 1% at 49.2° F. When pressure is released, liquid chlorine volatilizes into a greenish-yellow gas which is about two and one-half times as heavy as air. It is non-inflammable, non - explosive, and a non-conductor of electricity. Generally, in the absence of moisture it is not corrosive to common metals at temperatures below 212° F. Moist chlorine or aqueous solutions of chlorine require special equipment materials for handling.





Operating Diagram of the Chlorine Fractionating Column

A. Refrigerating Coil
B. Condensing purified chlorine
C. Purified chlorine outlet
D. Bubble cap
E. Downtake for reflux
F. Tray or plate
G. Raw chlorine inlet
H. Chloroform vapors
I. Chloroform and dissolved impurities
J. Steam inlet
K. Heating jacket
L. Condensed water
M. Drain for impurities

Chlorine has been proved to be the most efficient, flexible and economical agent for sterilizing water supplies; and it is also used as a sludge stabilizer, a taste and odor eliminator, a precipitating aid, and, in sewage treatment, for disinfection, for B.O.D. reduction and odor control. The quantity of chlorine required in water purification and sewage treatment processes depends upon the quality of water, the point of application, and the object desired. Penn Salt Liquid Chlorine is particularly adapted for such processes because of its high purity and freedom from objectionable "taffy" or chlorine gum, achieved by means of the specially designed Penn Salt fractionating column which eliminates practically all harmful impurities from the chlorine.

This Liquid Chlorine is supplied in seamless steel cylinders in sizes ranging from 10-lb. net to 150-lb. net. They comply with requirements of the Interstate Commerce Commission concerning specifications, retesting, loading, maintenance. Liquid Chlorine is also shipped in multiple-unit tank cars holding 15 containers of one ton each, and in single-unit tank cars of two sizes, 32,000 and 60,000-lb. respectively. The care with which all Pennsylvania Salt packages are cleaned and double-checked, coupled with the quality of Penn Salt Liquid Chlorine, assure maximum safety and convenience in chlorinator operation.

• PERCHLORON

Per*chloro*n is a high strength calcium hypochlorite, having a guaranteed active ingredient of not less than 70% calcium hypochlorite or available chlorine. It is free flowing, concentrated and retains its labeled strength for one year or more under normal storage conditions. It weighs approximately 52.5 pounds per cubic foot. It is composed of finely divided particles, all of which will pass a 20 mesh screen and be retained on a 65 mesh screen. It is quickly soluble in water, and is useful as a second line of defense for water purification in cases of emergency, when supplies of liquid chlorine may be temporarily cut off. Per*chloro*n is also used for sterilizing new mains, as well as clear wells and filters; valuable for sewage treatment, too. Many leading swimming pools sanitize their water with Per*chloro*n, use it to combat slime and algae growths, and to control athlete's foot by means of trays and spraying locker and washrooms. Per*chloro*n is supplied in handy-sized cans equipped with Kork-N-Seal covers, 9—5-lb. cans to the case. Also in 100-lb. drums.

● AMMONIA, Anhydrous

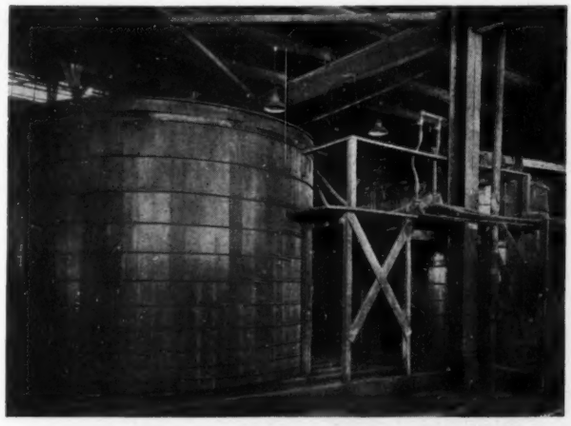
A colorless liquid which at 70° F. is 0.61 times as heavy as water, and weighs 38.0 lb. per cubic foot. When pressure is released, it volatilizes to a colorless gas of penetrating odor, which is 0.597 times as heavy as air at standard conditions. Dry ammonia is not corrosive to the common metals, but moist ammonia attacks copper and all its alloys, hence iron pipe and fittings are always recommended. Ammonia is exceedingly soluble in water. At 32° F., 1150 volumes of ammonia will dissolve in 1 volume of water, or 47.3% by weight.

This characteristic of ammonia is utilized in the dry feed ammoniators in water works. It is also useful in the chloramine process, in which ammonia is applied along with chlorine to prevent the formation of chlorinous, phenolic or medicinal tastes; and for stabilizing or prolonging the sterilizing action of chlorine. Ratios of ammonia to chlorine varying from 1:1 to 1:12 have been effective, with points of application ranging over the entire purification process. To prevent taste intensification, the ammonia must be applied before the chlorine.

Pennsylvania Salt Anhydrous Ammonia is supplied in special improved cylinders of seamless drawn steel which are light, strong and easy to handle and store. Gas may be withdrawn either with a cylinder standing upright on a scale for weighing, or with the cylinder lying horizontal, whichever is most convenient.

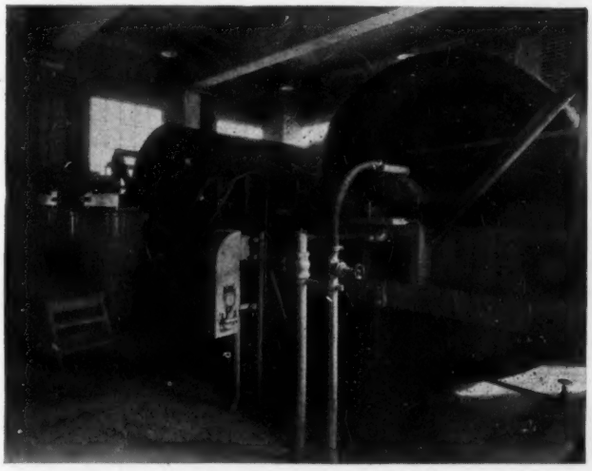
● FILTER ALUM (Sulphate of Alumina)

This product is the principal coagulant used in water purification; and Penn Salt Filter Alum has been adopted by many water works superintendents and engineers. Available in any quantity from a single bag or barrel to carload lots. Bags and barrels are paper lined as a protection against atmospheric moisture.



● FERRIC CHLORIDE

In liquid form it is an aqueous solution, the concentration of which is governed by the outside temperature and varies from 39% $FeCl_3$ in extremely cold weather to 45% in extremely hot weather. Pennsylvania Salt also supplies ferric chloride in an anhydrous form which is water-free and as near to 100% $FeCl_3$ as is permitted by impurities in the steel scrap from which it is made. Ferric chloride is a positive coagulant, producing clean-cut flocculation in economical doses. In most communities, depending upon shipping costs, ferric chloride offers vast savings over alum. The aqueous solution is shipped in rubber-lined tank cars holding 8,000 gallons and averaging 40,000 lb. of dissolved $FeCl_3$ per car. Anhydrous ferric chloride is shipped in non-returnable steel drums, 150 and 400 lb. sizes.



● SODIUM ALUMINATE

An alkaline compound of alumina and caustic soda, used both for softening water and as a combined coagulant and softener. Most effective in water requiring an alkali with the alum. Shipped in thin steel non-returnable drums, net weight 100 and 400 lb. each; and in 100-lb. moisture-proof burlap bags.

● SODA ASH
CHLORIDE OF LIME, and
CAUSTIC SODA

are among the other chemicals made by Pennsylvania Salt and used in water purification and sewage treatment. Ask us for detailed information and expert technical assistance.

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Ammonia Control Apparatus, Dry Chemical Feed Devices, Etc.

NEWARK, N. J.

"The Only Safe Water Is a Sterilized Water"

REPRESENTED IN

Abilene	Charlotte	Detroit	Kansas City	Minneapolis	San Francisco
Albany	Chicago	Greensboro	Knoxville	Oklahoma City	Seattle
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Bridgeport	Dallas	Jacksonville	Madison	Pittsburgh	Syracuse
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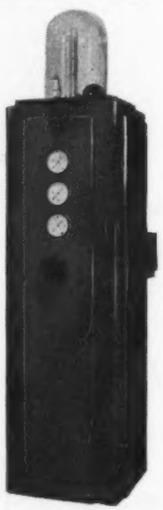
WALLACE & TIERNAN, Ltd., London, England

CHLORINATION FOR SAFETY

W&T Chlorination Trailer for self-powered protection in the case of emergencies requiring chlorination at any point in the system.

Continuous treatment by chlorine is the one method now almost universally used for protecting public water supplies from disease bacteria. Wallace & Tiernan equipment for this purpose now safeguards over 85% of America's public water supply. For permanent installations, W&T "Visible Vacuum" Chlorinators furnish closely controlled solution feed over a wide capacity range, with either manual or automatic regulation of the application rate. For small water supplies, W&T Hypochlorinators assure safety with simplicity and low cost.

For emergncy use, the Wallace & Tiernan Chlorination Trailer is self-powered. Designed for use at any point in the water system, this unit is particularly applicable to main sterilization, secondary chlorination of open reservoirs, in case of pollution from cross connections, in fact wherever and whenever chlorination may be required. Also available for use at any point in the system is the new W&T Portable Chlorinator which provides for compensated solution feed. Both of these units have been designed in accordance with information on English experience, as well as consultation with American military and civilian defense authorities.



W&T "Visible Vacuum" Chlorinator for automatic proportioning of chlorine to the flow of water. A companion unit with manual control is also available.

HYPOCHLORINATOR

Some chemicals, such as hypochlorites, are available in stable solution and present problems in dry feed which make it most desirable to apply them in solution form. The W&T Hypochlorinator is designed to feed such solutions as sterilizing agents, coagulants or corrosion inhibitors with accuracy and dependability.

TASTE AND ODOR CONTROL

Modern water treatment methods such as "breakpoint" chlorination and chlorine-ammonia (chloramine) treatment not only raise health protection standards but act to overcome taste and odor troubles due to algae, industrial wastes, and the like, thus furnishing a water that is more palatable as well as completely safe.

APPLICATION OF DRY CHEMICALS

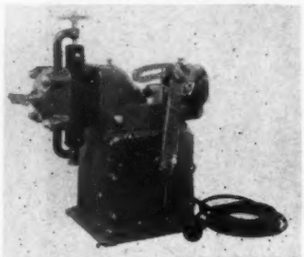
Wallace & Tiernan produces several types of dry chemical feeders for uniform, wide-range feed of such powdered chemicals as alum, lime, soda ash, carbon, etc. This dry chemical application has become particularly valuable, and is used extensively, in both sanitary and industrial water works.

W&T MOF Dry Chemical Feeder provides wide-range feed of various powdered chemicals.

W&T TECHNICAL SERVICE

For any water treatment problem Wallace & Tiernan representatives can provide competent technical assistance. These representatives will be glad to review your problem and make recommendations without obligation.

HELPFUL FREE BULLETINS



W&T Hypochlorinator for treatment of small water supplies is economical and simple to operate.

Technical bulletins available from W&T give complete specifications on each type of Chlorinator and other W&T equipment. Also available is current literature on the many phases of chlorination, ammoniation and dry or solution feed of chemicals.

PART 7

SEWAGE TREATMENT

WATER WORKS
& SEWERAGE

REFERENCE & DATA SECTION

1942

% PROPORTIONEERS, Inc. %

"EMERGENCY-CHEMICAL-FEEDER HEADQUARTERS"
9 NO. CODDING STREET, PROVIDENCE, R. I.
Representatives in Principal Cities

Raw Sewage Conditioning using Ferric Chloride and Lime can be controlled in proportion to variable flows thru the Venturi Tube, or over a Weir, measuring the influent. Ferr-O-Feeder can handle concentrated 43% ferric chloride or any dilutions; also ferrous salts and practically any other chemicals needed in sewage plants.

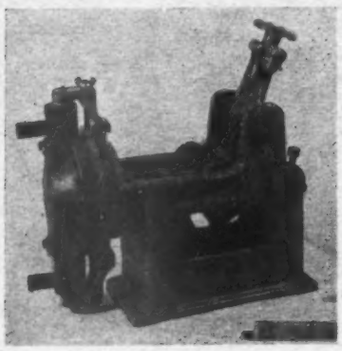


Fig. 1—Standard Ferr-O-Feeder

Sludge Dewatering—Sludge dewatering plants using vacuum filters, must automatically control coagulant administered. A Ferr-O-Feeder, used as an adjunct to the vacuum filter, measures ferric chloride and delivers it under pressure to proper point of application in mixing chamber. Ferr-O-Feeder not only accurately measures corrosive liquids but, due to positive displacement method, can deliver the chemical remotely to upper floors of the plant—wherever the filters and dewatering equipment may be located. This eliminates the need of additional rubber lined pumps for lifting or moving ferric chloride from storage to point of use. Ferric feeder is controlled by cross connection to sewage pumps; to drive motors of vacuum filters; or by belt or chain and sprocket connection to bucket elevators (see Fig. 3).

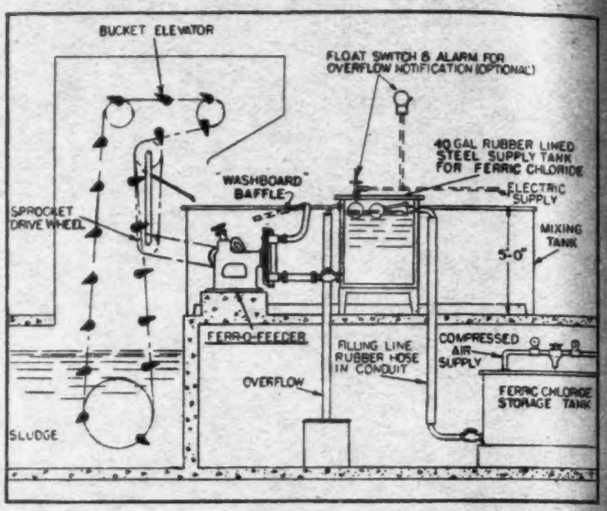


Fig. 3—Installation Diagram Ferric Chloride Feeder Controlled by Bucket Elevator

Chem-O-Cabinet is a single unit for permanent installation or for portable emergency operation, a unit that will feed any chemical used in sewage treatment. It is a complete installation, all ready for the operator to set in place, and tap into the line. As shown in Fig. 4, it is made up of the following: 85 lb. per square inch pressure proportioning pump (also capable of feeding into negative pressure zones), mounted on steel cabinet with all accessories including: parts to easily interchange for feeding various chemicals, folding rubber bag, Orthotolidine test kit, and spare parts for year's service.

Fig. 4—Che. -O-Cabinet

Chlor-O-Feeders for Odor Abatement—Hypo-Chlorite sterilization of sewage effluent (Fig. 5) is widely practiced in Airports, Army Camps and other small sewage plants for odor abatement. Depending upon local conditions, Chlor-O-Feeder chlorinates constantly; is manually started and stopped as required; is connected to automatically start and stop with the sewage pumps; or is operated, automatically controlled, from sewage syphon.

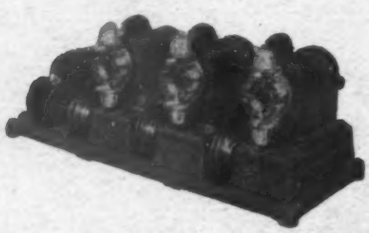


Fig. 2—Triplex Multi-Control Feeder

Multi-Control Feeders—Multiple feeding of several chemicals has been standardized so that 2, 3, 4, or more synchronized feeders, "ganged" on one drive mechanism (Fig. 2), can be ordered from stock.

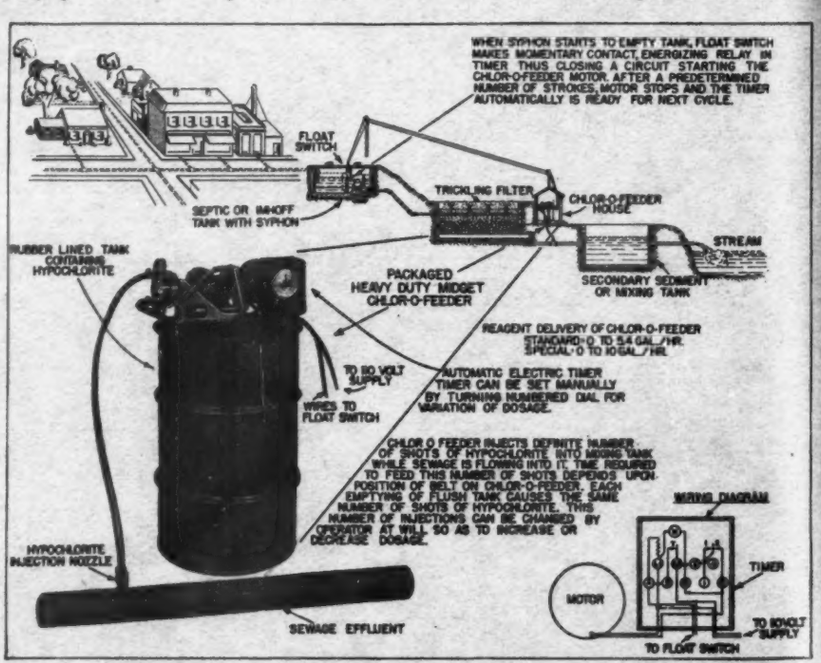

WHEN SYPHON STARTS TO EMPTY TANK, FLOAT SWITCH MAKES MOMENTARY CONTACT, ENERGIZING RELAY IN TIMER THUS CLOSING A CIRCUIT STARTING THE CHLOR-O-FEEDER MOTOR. AFTER A PREDETERMINED NUMBER OF STROKES, MOTOR STOPS AND THE TIMER AUTOMATICALLY IS READY FOR NEXT CYCLE.
FLOAT SWITCH
TRICKLING FILTER
CHLOR-O-FEEDER HOUSE
SEPTIC OR IMHOFF TANK WITH SYPHON
STREAM
RUBBER LINED TANK CONTAINING HYPOCHLORITE
PACKAGED HEAVY DUTY MIDGET CHLOR-O-FEEDER
SECONDARY SEDIMENT OR MIXING TANK
REAGENT DELIVERY OF CHLOR-O-FEEDER STANDARD-0 TO 5.4 GAL./HR. SPECIAL-'O TO 10 GAL./HR.
TO 110 VOLT SUPPLY
AUTOMATIC ELECTRIC TIMER TIMER CAN BE SET MANUALLY BY TURNING NUMBERED DIAL FOR VARIATION OF DOSAGE.
WIRES TO FLOAT SWITCH
CHLOR-O FEEDER INJECTS DEFINITE NUMBER OF SHOTS OF HYPOCHLORITE INTO MIXING TANK WHILE SEWAGE IS FLOWING INTO IT. TIME REQUIRED TO FEED THIS NUMBER OF SHOTS DEPENDS UPON POSITION OF BELT ON CHLOR-O-FEEDER. EACH EMPTYING OF FLUSH TANK CAUSES THE SAME NUMBER OF SHOTS OF HYPOCHLORITE. THIS NUMBER OF INJECTIONS CAN BE CHANGED BY OPERATOR AT WILL SO AS TO INCREASE OR DECREASE DOSAGE.
WIRING DIAGRAM
HYPOCHLORITE INJECTION NOZZLE
TIMER
MOTOR
TO 60 VOLT SUPPLY
SEWAGE EFFLUENT
TO FLOAT SWITCH

Fig. 5—Automatic and Proportional Treatment of Sewage with Hypo-Chlorite

PART II. SEWERAGE

JOINT ADMINISTRATION AND COLLECTION OF WATER AND SEWER ACCOUNTS

By LEONARD N. THOMPSON, Engineer and General Superintendent
Water Department, St. Paul, Minn.

FROM the outset of the work of the Committee on Joint Administration and Collection of Water and Sewer Accounts, it appeared that there existed a large amount of literature covering comprehensively the subject of sewer rental laws and the many types of sewer rental rate structures. Reference is made at the end of this report to several of these noteworthy publications. To those officials who are interested in the subject and wish to study forms of rate structures, the Committee suggests a review of these papers. The Committee acknowledges the use and study of these publications in the preparation of this report.

While in this report the terms "sewer rental" and "Sewer service charge" may be used interchangeably, the Committee favors the expression "sewer service charge" as more descriptive of the service rendered. This should be considered when preparing material for educational or publicity purposes. Where the sewerage system is already in existence and perhaps paid for, the owner-user sometimes wonders if the "sewer rental" charge means that he is in fact paying twice for the system.

The sewer service or rental charge method has been fairly well worked out, but its application has raised other problems in connection with administration, billing and collection. These problems have, in an increasing number of cases, fallen upon the water department. They have been described very aptly as several series of problems rather than one particular question. On general policy and administration problems little has been written, and in all the data available there has been little to indicate the best practice or to guide the executive.

With full realization that there exists a wide spread in local conditions, that laws, ordinances and local prejudices may be difficult to overcome and that definite standards, applicable under all conditions, are not now possible, it is the hope of the Committee that its conclusions may here produce discussion from which will finally develop definite recommendations to the effectual, economical and workable administrative machinery and practices. These recommendations will then be available as a guide to those now struggling to emerge from their difficulties and to those water works superintendents who suddenly find themselves confronted with the task of collecting both sewer and water charges. Only by full discussion by all those who are interested, and by exchange of information among those having knowledge and experience, can a workable outline be established for others to follow.

Water superintendents have generally hesitated to endorse the joint administration of sewer and water works. Particularly have they been skeptical of the effects on the water department of assuring the collection of sewer service charges. At the start, the difficulties appear many, and it is true that the joint administration, billing and collection of water and sewer bills introduce certain problems, but experience is showing that, with proper rules and methods of procedure, these difficulties are not insurmountable, nor do they appear to place the water department in an unfavorable position.

Sanitation and public water supply are both indispensable services in modern communities; although essentially complementary services, they have developed separately and in the great majority of cities are administered separately. The necessity for enlarged or improved sewage facilities has created new problems in financing, and, concurrently, means for more efficient administration. Not so long ago many cities were struggling under the burden of relief expenses and could not increase their bonded indebtedness. They feared to impose further increases in general property taxes. The revenue bond and service charge method of financing provided a practical solution for the many cities that were able to avail themselves of this method.

Today, with the inescapable necessity of increasing the national debt, state and municipal governments, accounting for approximately one-third of the total indebtedness, will be expected to keep expenses to a minimum. There probably will be some restraint on new issues and in this situation the adaptability of the revenue bond method will prove its worth. Financing out of revenue from service charges—the revenue bond method—which does not add to the bonded indebtedness of the municipality, has gained great favor.

The Committee has attempted to determine the effectiveness of existing legislation permitting the construction of sewerage systems and sewage disposal plants, and of the authority for bond issues, general tax levies and sewer service charges. Twenty-seven states now appear to have adequate satisfactory legislation. Eight report either no legislation at all or unsatisfactory legislation. Two states report that special enabling acts are required, and two report difficulty in the sale of revenue bonds, suggesting need for careful review by the authorities creating the power to issue bonds. In but five of the 42 states reporting did there appear to be restrictions on the creation of metropolitan districts, although a complete analysis of the state laws would have to be made and a legal opinion obtained before a conclusion could be made regarding the actual situation in any state. The fact remains that a great deal of the legislation or amendatory legislation has been passed within the past ten years, indicating the growth in sentiment for water and sanitary districts. Some of this, however, has been emergency legislation and must be given careful study before amendments are offered. While adequate legislation appears to be available in 27 states, in only a few of the states have the provisions been used to any extent.

Replies from 30 water superintendents to a questionnaire on legislation, rules and policies, indicate that the water works profession is far from agreement on its ideas concerning either rates or methods of administration.

The establishment of special boards for the joint administration of the operation of a water department and a sewage disposal plant appears to the Committee to be largely a matter for local decision. Responsibility for maintenance, operation and construction of sewerage systems and disposal works may not, properly, be of concern to the water works administration, often being delegated to other departments. The *actual control* of plant operations of water and sewerage systems under one administrative head, however, would appear to have certain distinct advantages. The *administrative functions,* including the duties of billing and collection, present problems so similar in nature and may effect such economies that control under one administrative head seems most logical and advisable.

Since a water department has already set up the machinery and facilities for both billing and collection, separation of these functions is a duplication of effort and an expense neither justified nor effectually criticized because of the added burden placed on the water works superintendent. Since, generally, those who are beneficiaries of the sewage disposal plant or sewage system of the city are water consumers, the water department already has available the most reliable and complete consumer ledger system.

There is a wide variation in the officials on whom responsibility is placed. A recent survey of 91 cities showed 14 different classifications of officials in charge of sewer systems; 13 of the 91 were water superintendents, 11 joint superintendents of both water and sewer systems. Of 94 cities surveyed, 18 held water departments responsible for sewer rental collections. Thus, it seems that the responsibility for the administration of sewer rental charges is assigned in many ways, depending upon statutory provisions, governmental organization and the basis of rental. With the increased demand for improved sanitary conditions, it is becoming customary to make the water department the responsible agency through which a financial plan and subsequent administration can be worked out.

A superintendent confronted with the problems of joint administration of the two services must, at the start, be concerned with certain definite problems:

1. The matter of legislation or statutory authority: It is highly desirable that such legislation: (1) clearly establish the administrative body and method of financing; (2) grant to such ad-

This paper was presented before the A.W.W.A., at Toronto, Canada, in 1941, by Mr. Thompson as Chairman of the Committee on Joint Administration and Collection of Water and Sewer Accounts and reproduced by permission of the Association.

ministrative body the power to adopt a rate schedule and necessary rules; (3) provide authority for the enforcement of all rules; and (4) make definite provision for the separation and disposition of all funds collected.

2. The determination of the amount of money to be raised by a sewer service charge after a policy has been established regarding the part of such charge that will be used to meet costs of operation, maintenance, betterments, extensions and debt service: When the sewer service charge is based on water consumption the superintendent can make a reasonable estimate of the probable returns. It is desirable that this sum be such that it will be reasonably constant over several years, in order to avoid upsetting charges once they are established. For this purpose it is wise to design rates that will produce a slight surplus which may be used as a cushion against increased costs of sewage treatment or fluctuation in water consumption.

3. The method of raising the desired revenue.

4. The methods of billing and collection and control or accounting.

5. The adoption, by the administrative body, of local rules and ordinances governing the matter of collections, discontinuance of service, discounts or penalties, etc.

With the present high tax rates and, in many instances, tax limitations, every means is being sought to find new sources of revenue. The primary purpose of a sewer rental fund, however, should be to provide for the proper financing of the maintenance and operating costs of the sewage system and sewage treatment works. Practice has shown a wide variation in the extent to which such revenues are relied upon to meet capital, operating and maintenance costs, but the Committee feels that consideration should be given first to the combined method of financing, i.e., assessing the cost of construction against the property benefited and making a service charge for maintenance and operation, with authority to transfer any surplus income from time to time to amortization of the funded debt. Another variation of this method is to include in the service charge the cost of the treatment but not of the sewerage system itself. The revenue bond method for the entire cost is a special consideration and not susceptible to conclusive recommendations.

Installation of a sewer system and disposal plant is beneficial to all properties, even to vacant property, by enhancement of potential values, and therefore, should be taxed for the costs of these improvements. The costs of maintenance and operation are attributable to and equitably chargeable to the users of the works. It is realized by the Committee that tax-exempt property will escape any payment of the capital costs, but legal opinion seems to indicate that sewer rental costs must be uniform and cannot be increased to the user of the system, located on tax-exempt property, when such increases are ostensibly for the purpose of collecting the equivalent of the tax item for construction.

About twenty different forms of sewer rental or sewer service charges are now existent, based upon uniform charges, the quantity of water consumed, the number and type of plumbing fixtures, the number of persons served, the type of premises, the character of the sewage, or upon a combination of one or more of the above methods. The water superintendent, as administrator of such collections, should be vitally interested in and consulted in the establishment of any sewer rental rate structure. While the burden of responsibility for the rates should remain with the sewer division or the city administration, it is highly desirable that they be made with the advice and approval of the water works executive. In establishing the basis, the portion of the total cost which can properly be borne by the city as a whole, i. e., collected by taxation, and the balance to be collected as a reasonable charge against the users, in proportion to the individual benefits derived, must first be determined.

A discussion of the many methods or bases for sewer rentals is covered in the several publications previously referred to, but a study of the many methods and the apparent trend through experience prompts the Committee to favor a charge based on the metered water consumption, either as a percentage of the water bill, or directly on a consumption basis. Directly on a consumption basis, the billing may be at a uniform rate or a step rate. A flat rate is not fair to the small consumer. A rate based on fixtures is difficult to administer. The metered-water method is the closest approximation to the use of system that is practical of application. It is dependent upon complete metering, and modifications have to be taken into account for private supplies and such industries as use large quantities of water which are not discharged into the sewer system. When the water supply is not metered, a flat rate based on the size of the water service or connection, or a charge established as a percentage of the water bill, would produce an approximation of the foregoing method.

The cities of St. Paul, Minneapolis and Detroit have sewer rentals which are typical of the three methods based, directly or indirectly, on water consumption. All three methods have been operating very successfully.

Minneapolis bills for water at the uniform rate of 7½ cents per 100 cu. ft. Sewer rental charges, which are also based on the metered water consumption, are on a sliding rate scale, as follows:

First	100,000 cu. ft.	@ 2.8c	per 100 cu. ft.
Next	200,000 cu. ft.	@ 1.5c	per 100 cu. ft.
All over	300,000 cu. ft.	@ 0.75c	per 100 cu. ft.

The minimum bill rendered is 37 cents.

For one and two-family homes the winter quarter water consumption is used as the basis for sewer rental charges throughout the year. The owner or occupant of this type of property is thus relieved of paying a sewer rental charge on water consumed for lawn sprinkling. Large consumers, of course, receive the benefit of the sliding scale. The annual revenue from sewer rentals is designed to care for operation and maintenance, 60 per cent of the fixed charges of the treatment plant and 30 per cent of the fixed charges on intercepting sewers. The balance of the costs are raised by a mill tax.

St. Paul uses a step rate for water consumption plus a fixed or service charge based on the size of the water meter. The sewer rental charges are only indirectly based on water consumption, being based upon the size of the water meter rather than on consumption directly, as follows:

Size of Meter	Annual Water Service or Demand Charge	Annual Sewer Rental Charges
⅝ in.	$ 3.00	$ 2.40
¾ in.	4.20	3.00
1 in.	7.20	5.00
1¼ in.	10.20	9.00
1½ in.	13.20	15.00
2 in.	27.00	30.00
3 in.	60.00	75.00
4 in.	120.00	180.00
6 in.	240.00	360.00
8 in.	420.00	630.00
10 in.	600.00	900 00
12 in.	.....	1,350.00

The total collections for sewer rentals are used only for costs of maintenance and operation. This city reports that the method has worked well except that, since both the service charge for water and the sewer rental charges are based on the meter size, the department has received several hundred requests for a reduction in the size of the water meters. Reductions granted have, of course, reduced both water revenues and sewer rentals.

Detroit has a three-step water rate plus a service charge based on the size of the meter. The sewer rental rate of 11 cents per 1,000 cu. ft. of water consumed is added to each step of the water rates, and water consumed is billed at the one combined rate to include both water and sewage disposal, as follows:

Water Consumption Charge	Sewage Disposal Rate Per 1,000 Cu. Ft.	Total Rate Per 1,000 Cu. Ft.
First 10,000 cu. ft. per month 78c per 1,000 cu. ft.	11c	89c
Next 900,000 cu. ft. per month 60c per 1,000 cu. ft.	11c	71c
All over 100,000 cu. ft. per month 48c per 1,000 cu. ft.	11c	59c

The service charge is added to consumption charge and all shown as one item on the bill.

In certain localities the presence of one or more industries may so affect the strength or character of the sewage, due to the degree of pollution, that some account must be taken of it in the rate structure. This is particularly true when the cost of operating a sewage disposal plant is involved. Also, in certain industries, where a large amount of water is consumed, provision may be made to discharge the industrial waste so that little if any use is made of the sewage disposal system, or even the sanitary or storm systems themselves. While some cities take no account of this factor, it seems fair to reason that, when a large percentage of the water used is not returned to the sewers, some adjustment in the sewer service charge is proper and even necessary to meet statutory requirements. While the enabling act should provide the authority for such a change, it is the opinion of the Committee that the basic charges, based on water consumption, should still be continued, and such conditions treated as special cases, making equitable adjustments in the charges, and so preserving the simplicity of the general rate structure. The enabling act should give the administration or those invested with power to establish the

rates, proper latitude to make certain uniform adjustments or exceptions to the rate structure.

Many cities are confronted with the problem of private sources of water supply, the water from which finds its way into the public sewer system. Authority for the billing of such accounts for the sewer service charge must be provided. There seems to be no reason why the same rates cannot be applied here as to users of the public water supply.

In St. Paul and Minneapolis there are 376 private wells, producing approximately 40 m.g.d. The two cities report favorably on the complete metering of the private supplies accomplished by ordinance, the sewer rental billing made in Minneapolis being on the water pumped from the private wells, and in St. Paul on the size of the meter as set on the well.

In these cities, where the private supplies have been metered for about eighteen months, it is reported that there has been no particular criticism. In both cities each case was individually investigated and the owner advised regarding type and size of meter. Perhaps the greatest difficulty experienced was the stoppage of meters due to sand pumped from the wells. In St. Paul, where the charges are based on the size of the well meter, the billing is continued until a well is reported out of service and sealed. The installations of small wells for air-conditioning, which are not used during the winter months, are billed throughout the year.

Ordinances should provide for the registration with the billing agency of all old and new sources of private water supplies. These meters should be read and treated as any other account. Since the department has no method of discontinuing such private supplies for non-payment, provision should be made to place delinquencies on the tax rolls or to file them as a lien upon the property.

The trend toward suburban development in many cities has become a real problem. Those who move outside the corporate limits of the city for various reasons, in some cases to avoid city taxation, demand the same utility services they enjoyed in the city. When tax funds have been used to construct and maintain a sewerage system and/or a sewage disposal plant it seems unfair that such facilities should be placed at the disposal of non-residents at less than actual costs. When metropolitan districts are established to furnish utility service to such areas, it is highly desirable that sewer rental charges be increased to represent at least the equivalent amount paid by those taxpayers who are or have paid for the construction of the utilities services. The Committee feels that there is every justification for the creation of metropolitan utility districts, but where those consumers of the service are beyond the tax jurisdiction of the municipality, the payment for such service should represent at least the equivalent of the sum total payments made directly or indirectly by the consumer for like service inside the city, including all costs of amortization, interest, depreciation, maintenance and service.

The difficulties encountered in the collection of sewer service charges are not very great once a sound and workable method is adopted. Sewer bills or sewer service charges may be made separately and entirely independently of the water bill, separately and attached to the water bill, included in the amount of the water bill, or shown as a separate item on the water bill.

There is a natural antipathy among water works men toward confusing the water bill with charges which are primarily of no concern to the water department. Placing additional charges on a water bill, it is felt, will conjure up in the mind of the consumer the idea of an increased water bill. For this reason the practice of making separate bills has often been employed. The committee is of the opinion that the additional expense involved in issuing separate bills is not justified, that experience is proving that a water bill, carefully prepared and explanatory, will neither confuse the consumer nor bring undue criticism upon the water department. It is reported that during the initial stages many inquiries are received but that once the additional charge is understood, the complaints are few.

Simplicity in rate structure and in billing is highly desirable. One of the strongest arguments in favor of a rate based on water consumption is the ease with which the charge may be included with or on the water bill. The bill should be clear and should properly indicate each charge. A statement of the rate schedule is highly advisable. Proper publicity prior to the initiation of the combined method of billing and proper explanation have been found to work successfully and to overcome the fears of the superintendent. Reports indicate little, if any, increased delinquency in the payment of water bills. A printed notice on all water bills to the effect that the water department is acting only as the collection agency for sewer rental charges and that the funds are maintained separately had proved helpful in a number of cases.

Practically all public utility types of billing machines can be so constructed as to indicate the water charge and the sewer rental charges separately, and to tabulate or accumulate the two accounts separately for proper accounting purposes. This process is available even to the extent of duplicating or repeat-printing the amounts of the bill proper and on the cashier's stub. Much clerical and consumer's time may be saved and a clear record kept if all collections made are credited on the one ledger card under proper headings. Accounting control and trial balances are simplified. Separate accounting of each fund is highly desirable, and since the water department is acting only as the collection agency, the funds collected for sewer rental purposes should be credited directly to such an account and turned over to the proper authorities for disposition and disbursement. Colored ledger cards for carrying the accounts of private supplies are desirable and helpful in distinguishing the type of supply easily and quickly, without interference with the financial control system.

Some provision must be formulated in the case of delinquents. Simplicity indicates that the same discount rate or penalty should be applied to sewer and water accounts.

The water department should have the right to instigate all rules governing the method of collection, time or period of billing, to correspond with the regular water billing periods, the rules for collection of delinquent accounts, turn-off for non payment, etc. Since it is not practicable to shut off a sewer connection, the most logical and practicable method of forcing payment of sewer rental charges is to demand that they be paid with the water bill, with right to deny service of both. While on the face of it, it does not seem fair to a water department to be required to deny service to a water consumer because he refuses to pay a sewer rental charge, here again experience shows that the percentage of delinquencies is very small, varying usually from zero to 10 per cent in 37 cities, with one city reporting 20 per cent and two as high as 30 per cent in the depression period. There is no reason to believe that the sewer rental charge on a water bill has increased delinquency.

In practice it will be found that numerous accounts are not connected to the sewer system and, therefore, are not subject to the sewer service charges. In one city a charge is made where the sewer is available, irrespective of whether actual connection is made or not. In another, no charge is made until actual connection is made. In initiating the sewer rental charges in the latter city, the charge, initially, placed on all ledger accounts and billed until complaints and investigation proved the error.

When charges are based on the water consumed and allowance made for lawn sprinkling, it is the usual practice to establish, by a review of the reading sheets, the normal or average consumption for one billing period at each premise as indicated in the off-sprinkling or winter months and to indicate the amount so arrived at on the reading sheets and ledger cards as the average domestic consumption. The sewer service charge is then applied to this same consumption at each billing period. Established percentages of the water charge or fixed charges, when these methods are used, and any other information necessary to billing should be entered on both reading sheets and ledgers. The water superintendent should see to it that his department is reimbursed for all expenses incurred in carrying this added service. These costs may include additional billing equipment, the cost of changing over some equipment to meet new demands, the cost of new ledgers, a fair and proportional share of the postage, clerical and miscellaneous expenses.

The water superintendent should have the complete cooperation of the public works department, sewer department or whatever agency controls the installation of new sewer connections, in order that records may be completely and accurately up to date. Insofar as possible each department should be self-sustaining, free from any political interference and in full control of the revenue received, subject only to the limitation that they be expended for water works and sewerage services and for no other purpose.

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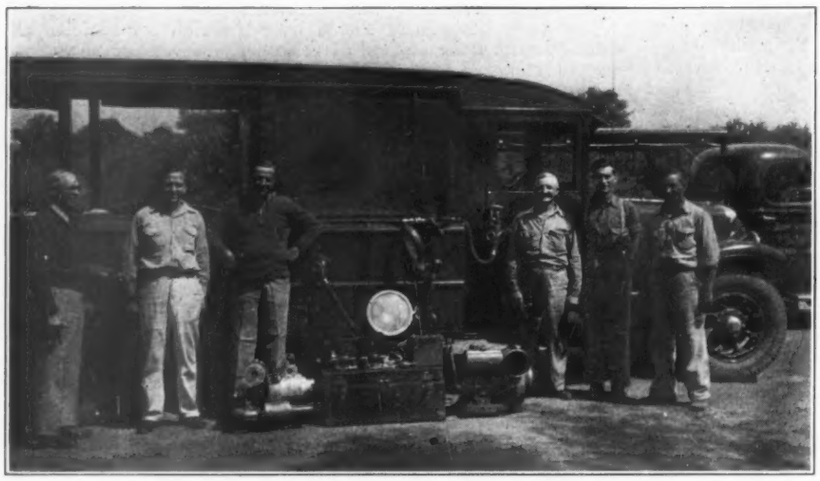
SEWER SERVICE AND MAINTENANCE

Radio Equipped Service and Maintenance Truck Proves Its Value

By EDWARD P. DECHER

Ass't. Secretary and Purchasing Agent
The Joint Meeting, Newark, N. J.

First, it should be explained that the Joint Meeting is a Sewer Commission and is comprised of the following eleven municipalities: City of East Orange, Town of Irvington, Township of Maplewood, Township of Milburn, City of Newark, Village of South Orange, and the Town of West Orange, all being in the County of Essex. In the County of Union are the Township of Union, Township of Hillside, Boro of Roselle Park, City of Summit.



No. 1.—Radio Equipped Maintenance and Service Truck and Equipment (Henry Decher, Ass't Foreman (left) and Crew)

The Joint Trunk Sewer

The Joint Trunk Sewer is constructed within the boundaries of the aforementioned municipalities. The original sewer was built in the year 1900 and is approximately 23 miles in length. A Supplementary Joint Trunk Sewer was completed in the year 1930 to give a total of 54 miles of main trunk sewer in all.

The Joint Trunk Sewer at the present time is serving an estimated population of about 305,000. The Sewage Treatment Plant is located in the City of Elizabeth, the final effluent discharging into Arthur Kill. One can readily see that should our men and equipment be working in the Town of West Orange and an emergency should arise in the Boro of Roselle Park or at our Treatment Plant (the plant being about 12 miles from the Town of West Orange) a difficult task would be encountered in contacting the men or securing needed equipment.

Our Truck Now Radio Equipped

Because of the distances involved it was deemed advisable by the Hon. Peter A. Smith, Chairman of the Joint Meeting, to equip one truck, at least, with a short-wave receiving set for the purpose of reaching our maintenance and service crew in the shortest possible time in case of an emergency or a complaint received which justified attention with least delay.

The radio set was purchased at a cost of $170.00 and installed on our three ton International truck.

The following is a list of the equipment carried on our two motor trucks:

1 Hydrogen Sulfide Detector.
1 Wolf Safety Lamp.
1 Combination Velocity Blower Hose Mask with Safety Harnesses.
1 Carbon Monoxide Detector.
2 Canister Type Gas Masks.
Carbon Monoxide Detector Ampoules.
2 Pairs Chippers Goggles.
1 2½" Portable Air Blower.
1 Combustible Gas Indicator.
1 Industrial First Air Kit.
4 Extra Safety Belts with ropes attached. Salt tablets for use in the prevention of heat sickness.
1 1500 Watt Portable Electric Generator and Floodlights.

The Joint Meeting has six employees on General Sewer Maintenance (see photo No. 1) and all of these men have taken a course in First Aid which course was given by the Newark Safety Council. Besides being capable of administering first aid, all of the men are trained in the proper use and operation of the many safety devices carried on our equipment at all times.

Our ment are especially instructed in the use of the hose and canister type masks. The Joint Meeting will not permit any of its men to enter a sewer or any sub-surface structure with a *canister* type mask which is of no value in oxygen deficient atmospheres.

We have heard of water service trucks that have been radio equipped. However, at the present time, I know of no other sewer truck equipped the same as the one owned and operated by the Joint Meeting, and I believe that it is the first sewer truck in the United States equipped with radio.

In photograph No. 1 is seen the two maintenance trucks (the larger being the radio equipped unit), some of the equipment

No. 2.—Some of the Equipment (See text for description and uses)

listed above (see Photo No. 2), and the General Maintenance Crew.

Equipment

Portable Generator

On the left is our indispensable Homelite Portable Generator good for 110 volts D.C. and 1250 Watts. In center, the floodlight. Both are products of the Homelite Corporation of Port Chester, N. Y.

With this generator we have several electrical tools and flood lights. These electrical tools have been found to be very satisfactory. We have never at any time found ourselves without proper lighting when emergency work is performed at night. We have approximately 200 feet of special extension cord, should the necessity ever require special lighting in our large sewers when repairs are made. A good portion of our sewers are in outlying territory where electric current to be supplied from a nearby house is impossible.

It may be interesting to note that the Joint Meeting has two cast iron pipe sewers, one being 36 inches in diameter and the other 54 inches, which run parallel and lie on the top of the ground in the Township of Union and each being approximately 1500 feet in length without any manholes. It has been recommended by the Chief Engineer—Leslie E. West—that at least four manholes be built on each line and the type recommended are Hat-Flanges, with bolted covers. To install these Hat-Flanges our portable generator will play a very important part, that is for furnishing the current to drill the necessary holes in the present pipe in order to fasten on the Hat Flanges. If it were not for this machine it would require drilling these holes by hand or renting the equipment.

On two occasions power failures were encountered at the Treatment Plant. We were able to supply the necessary light until the current was restored. Our generator has proven a very sound investment, if not an indispensable one.

Blower, Hose Masks and Gas Detectors

The next item in this photograph is the trunk-like case which contains the blower and the hose type gas masks. This piece of equipment is manufactured by the Davis Emergency Equipment Company, Inc. of New York City. On the top of this case are two carbon monoxide detectors, two hydogent sulfide detectors, and one combustible gas indicator. The last two items of equipment are products of the Mine Safety Appliance Co. of Pittsburgh, Pa.

Portable Air Blower

The last item in this photograph is the portable air blower (on the right) manufactured by the B. F. Sturtevant Company of Boston.

This piece of equipment has proven very satisfactory and is used in ventilating sewers before men are allowed to enter. It has also been used at our Treatment Blant in drying out the tunnels. There also appears on this photograph, hanging from the side of the truck, the headpiece and safety belt of the gas mask. This equipment as shown is carried at all times with the necessary First Aid equipment on this truck. A combustible gas indicator manufactured by the Davis Emergency Equipment Co., together with the duplication of the carbon monoxide and hydrogen sulfide detectors are carried on our other truck, and another set is stationed at our Treatment Plant.

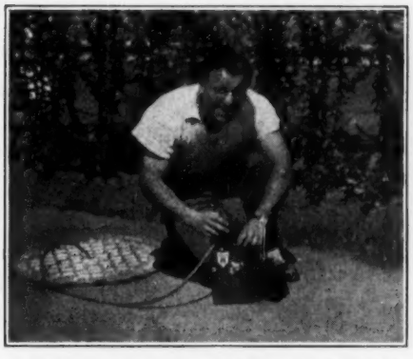
The writer believes that no municipality can afford to be without the necessary safety equipment for the protection of their employees. While the cost of the aforementioned equipment is most reasonable, it is priceless in the event of an emergency.

No. 3.—We find the Flexible Rod to Have Many Advantages Looking into the manhole are Henry Decher, Foreman, and (right) Corey W. Sanford, Superintendent of Sewers.

No. 4.—Pollard's Portable Platform Derrick (On the platform, a turbine wench; Superintendent Sanford, Portable Homelite Generator and Flood Light)

Flexible Sewer Rods

The Flexible Sewer Rod shown in Photograph No. 3 has proven to be a very satisfactory piece of equipment. This piece of equipment, manufactured by the Flexible Sewer Rod Co. of Los Angeles has many advantages, such as can be seen. One can readily understand that the old method used in removing an obstruction in a sewer that only one man could be placed in a manhole, in a cramped position, at a time, thereby reducing his strength to a minimum when working. With a flexible sewer rod you can notice in the photograph that more than one man can be used and greater



No. 5.—Our Chief Engineer, Leslie E. West, Demonstrates the Test for Poisonous and Combustible Gases

pressure exerted, and the safety feature is that the men are on top of the ground at all times during this particular operation. We have found that an obstruction can be moved much faster with this piece of equipment than the methods used heretofore, and that more territory can be covered in a shorter time. There are also many other advantages.

Portable Derrick

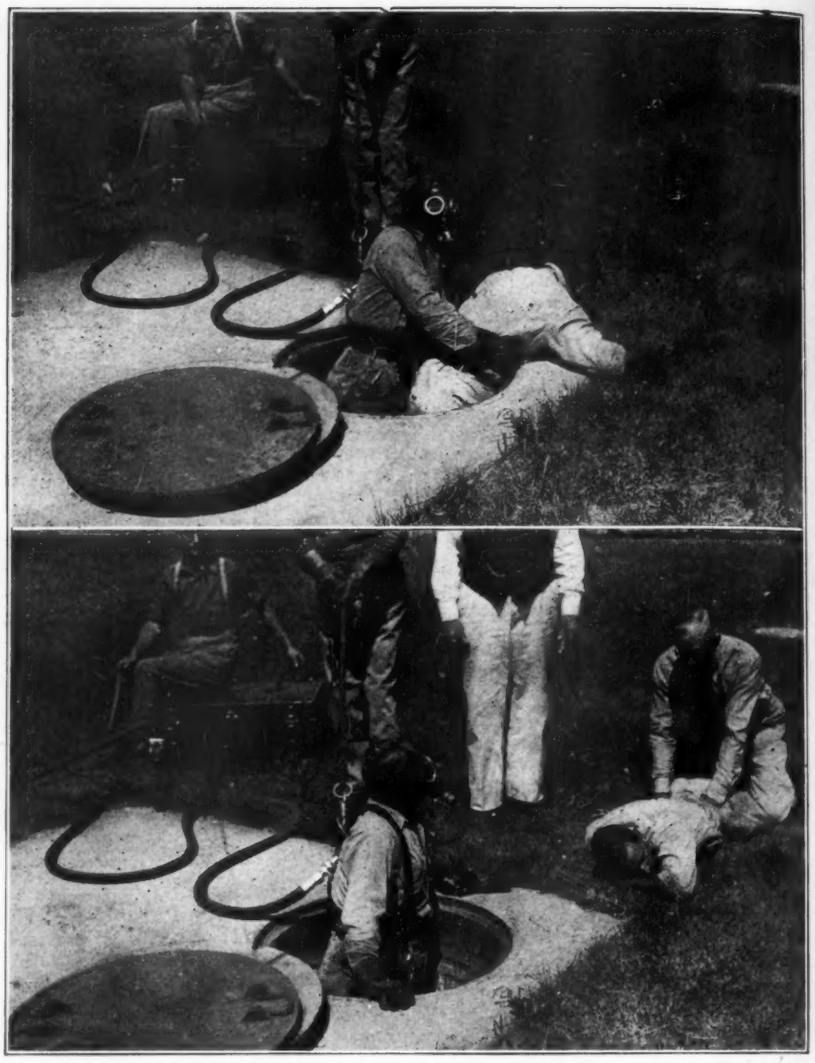
The portable derrick shown in Photograph No. 4, manufactured by The G. J. Pollard Company of Brooklyn, N. Y., is known as the Pollard Portable Derrick. The platform on this derrick is large enough to transport our two Turbine Sewer Cleaning Wenches (Turbine Sewer Machine Co. of Milwaukee) with the drum and cables intact.

These wenches, with the drums and cables, are rather heavy but can be easily placed on the derrick platform without much effort, due to the fact that the platform is only 12 inches above the ground. This platform derrick is equipped with a set of small rubber wheels in the center, and is towed on the rear of our truck from one job to the other.

The derrick has a lifting capacity of 1000 lbs. and can be swung in any position desired. It has been used to lower pipe on some of our repair jobs, and used in raising tilting buckets out of manholes during sewer cleaning operations. It has also been used very successfully in loading heavy manhole heads and pipe on our truck, therefore making loading much safer. This piece of equipment has proved highly useful.

Rescue and First Aid Practice

Photographs No. 6 and No. 7 show our employees giving a demonstration of the proper method of rescuing a man, should he be overcome while working. There may be a possibility that the reader seeing the photograph may criticize the fact that we permitted a man to enter a sewer or chamber without the proper equipment, however, this is not the case with the Joint Meeting. I believe, though, that the fact can be appreciated that it is a hard task to have a man working in a sewer wearing a gas mask continuously, if the conditions under which he is working are absolutely safe. Extensive tests are made before any man is permitted to enter any of our sewers. We have quite a number of meter chambers which are far above the sewer line itself. These must be entered by our employees each week to change the meter charts, and in performing this duty it is not always necessary for a man to be equipped with a mask if conditions are safe, however, one can never tell when an employee may be suddenly attacked by some gas. For this reason our employees must go through a rehearsal such as pictured, so that they do not lose their technique and ability in case of an emergency.



Nos. 6 and 7.—Rescue and Resuscitation Practice Is a Requirement of the Joint Meeting

Compensation Insurance

The Joint Meeting carries compensation insurance, which we believe is very necessary. Regardless of how minor an injury may be, even to a small scratch on the finger, the employee must go to a doctor for the necessary treatment. This is to insure their safety and to minimize claims against the Joint Meeting.

Last year all of the employees of the Joint Meeting were inoculated against typhoid fever. This was paid for by the Joint Meeting as a safeguard to its employees. The Joint Meeting makes every effort to see that its employees are protected from any hazards and makes it a practice to have a safety engineer from the insurance company make regular inspections of the equipment and Treatment Plant every month. And, at the same time the inspection is made a safety meeting is held by our em-employees, they having an opportunity to discuss problems pertaining to the plant with the safety engineer.

Safety Equipment Demonstrations

In June, 1938 the Commissioners of the Joint Meeting held a special meeting at the Treatment Plant for the purpose of gaining as much knowledge as possible for themselves and the employees on safety measures. The principle speakers at the meeting were Mr. E. M. McCool of the Mine Safety Appliance Co., and Mr. L. W. Brendlen of the Davis Emergency Equipment Co. They gave a very splendid lecture and demonstration on the proper uses of the various safety devices used in connection with sewer work. This meeting was attended by approximately 100 officials connected with the municipal sewer departments in Essex and Union Counties, New Jersey.

Employee Suggestion-Box and Prize Contest

There is installed on the wall in the Treatment Plant a box known as the Suggestion-Box in which suggestions are deposited by our employees. Employees have continuously placed suggestions in this box and, after being given careful consideration, the most practical are tried. A number of the suggestions submitted have been found to be decidedly beneficial. It is a commonly known fact that men in constant contact with equipment are those most able to express its advantages and observe wherein improvements would bring about better results. The Commissioners of the Joint Meeting have discovered that many of these suggestions have resulted in a considerable saving in dollars. For this reason the Commissioners of the Joint Meeting have set up two prizes for a contest which is now in progress, giving each employee an opportunity to express his views as to what in his opinion would better serve the Joint Meeting as operation of the Treatment Plant, maintenance of the sewers, safety of the employees, or any other item pertaining to the works in general.

SINCE 1901

W. H. STEWART

Sewer Cleaning Equipment

P. O. Box 581
JACKSONVILLE, FLA.

P. O. Box 767
SYRACUSE, N. Y.

STEWART WOOD AND STEEL SEWER RODS

JUMBO No. 10 HEAVY DUTY WOOD RODS

Lengths:
2½, 3, 3½, and 4 ft.

Woodstock:
Selected hickory 1⅜"x1½" octagon

Couplings:
Strong, Malleable Iron

Triple Lock heavy duty sewer rod. Impossible to buckle or uncouple in the sewer. The tongue and groove eliminate wear on the hook, increasing the length of service.

Rods may be coupled or uncoupled on street surface. Will stand forcing with jack or windlass.

Free Trial—The Rods must Pay for themselves.

SECTIONAL STEEL RODS

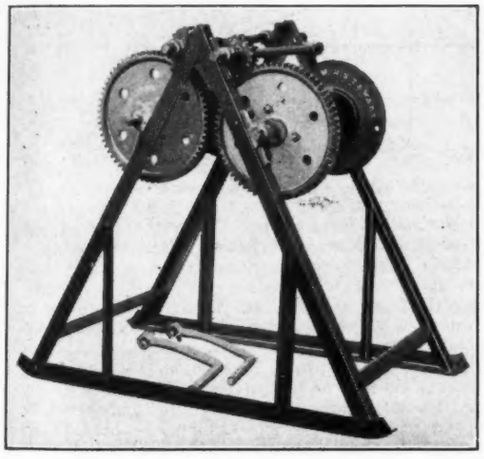
Double Lock highly tempered spring steel rods

Rod length 3 ft., 5 ft. or 10 ft.

Rods connect by sliding in from the side. When the coupling is closed, a double lock prevents opening while in use.

May be operated from street level.

Two Man Sewer Cleaning Machine



The Stewart single windlass "two-man" machine operates entirely over one manhole. The "two-man" windlass is a double drum machine; one drum holds the cable that pulls the bucket or tool into the sewer, the other drum holds the cable that pulls the bucket or tool out of the sewer.

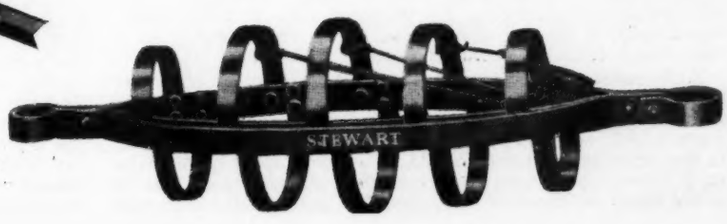
Rod Guide and Holding Frame

No. 22 Spear Screw—4" to 10"

No. 12—Open Screw— to

Guard Cage Collapsible Bucket—4" to 36"

No. 9 Stewart Root Cutter—4" to 15"



SEWER FLUSHING

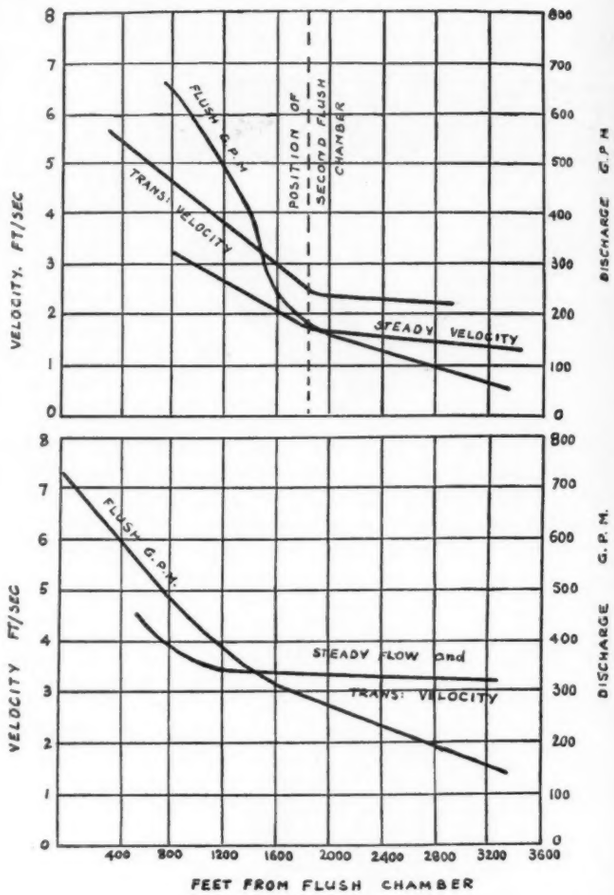
Good and Indifferent Practices

By JOHN D. WATSON
Consulting Engineer, Ruislip, England

This article reveals much pertinent to "Sewer Flushing" practices and presents what may be considered satisfactory flushing and what will prove a waste of effort and funds. The all important depth of flow in flushing, as compared to velocity flow without the needed depth, is pointedly emphasized. If we interpret correctly, many readers will find it necessary to consider some of our existing pseudo-flushing practices as little more than sewer "rinsing," after reading the depth—velocity discussion by Mr. Watson—an authority with a wealth of experience and years of observation to draw upon.

The basic condition upon which calculations for sewer flow should be made is that the sewer have a self-cleaning velocity. In other words, it should never tend to silt up even though the dry weather flow condition persists for long periods while at the same time it must be capable of taking storm water, unless it is wholly diverted from it. Provided they are properly constructed it is not usually difficult to give sewers a sufficient fall for this condition to be fulfilled. Main sewers will work with little or no trouble when laid on a grade of 1:1000 or less and, when the London Main Drainage was designed some 70 years ago, experiments showed that a velocity of 1½ miles per hour was sufficient, and very little cleaning is necessary in these sewers today. They vary from the familiar oval section of 4-ft. x 2-ft. and 8-in. to circular sewers of 12-ft. diameter. They are mainly built of brick.

Trouble is rather more likely to occur in the smaller branch sewers which have to be put in of a size to allow of increasing population so that for perhaps 10 or 20 years, normal flows are insufficient to maintain a self-cleansing velocity; and, while it is usually possible to divert surface water into them, it usually has to be kept out in order to save pumping and purification costs. The system adopted at one time at Hamburg, of constantly flushing the main sewers from a small river, enabled them to be laid at 1:3000, and to be run practically half full continuously, but that principle has rarely been adopted. The usual practice, when artificial flushing is resorted to, being either to provide gates to dam back the flow and then to release the pent up sewage for the purpose; or the use of tanks operated by an automatic syphon, the latter arrangement being as a rule the better one.



Curves Revealing Relationships Between Depth of Sewer Flush (Rate of Flush Discharge) and Effects Down-Sewer

The Great Importance of Depth in Flushing

When arranging for it the important points to bear in mind are, that the flush is not going to be effective over any great distance, and that it is the depth of flow over the invert of a sewer which is the most effective in moving the material which is the main cause of obstruction. That of course, is the condition intended to be provided by the oval sewer, silt being usually the main cause of the trouble in the present connection. In the form of road detritus, though it may reach the sewers mainly in times of storm when there should be sufficient velocity to carry it to the outfall, road detritus in the average condition has been found by experiment to require a velocity of nearly 1-ft./sec. to keep it on the move and if small pieces of broken stone and similar material get into the sewer (which by some unaccountable means they do) such, according to size, will require a velocity of 2½ to 3½-ft./sec. to move them. Incidentally, it is such obstructions in the first instance, as a rule, which cause a general obstruction to build up.

Such material always moves along with a speed of travel less than that of the stream (usually not more than half) and though 2½-ft./sec. flow velocity may move a piece of stone it will only barely do so in 1-in. depth of water. But, if the depth be increased to 6-in. it will roll along quite easily at 2-ft./sec., confirming the contention already made that it is the depth of liquid in the sewer that is the really important factor in keeping it clean. Therefore, the conclusion to be reached, is that, in circular sewers at all events and more particularly in the average branch up to 30-in. dia., the basic cause of silting is *insufficient depth* of flow *rather than velocity;* and, especially is this evident in lateral sewers which only receive intermittent discharges from the dwellings connected to them. Thus, deposits commence which ought to be periodically flushed away because if they are not removed, although they might not immediately render the sewer inactive, they cause a filmy growth (slime) to appear on the pipe wall. This growth in turn further reduces the velocity, and so matters go from bad to worse with the additional evil of the sewage becoming septic and producing large volumes of sewer gas, with its well known attendant evils.

This can be demonstrated in a simple manner by purposely putting some coarse sand or fine gravel in a sewer. Then it will be found that while motion is set up by dragging action, the particles are more or less lifted up into the stream and further motion is carried on by the added effect of suspension. The greater volume of material is naturally carried in the lower layers of the stream, the total quantity being proportional to the depth. Motion, too, will be seen to be from the sides of the sewer towards the centre, the major portion of the suspended matter being carried along the centre of the stream. The amount and the size of the material being carried in suspension

depends upon the velocity of the stream and its depth of flow. But, to a much greater extent depth is controlling, because in appreciable depth of liquid the particles are thrown to a greater height; and, as the velocity of descent of the particles is the same in both cases, the deep stream carries the particle further owing to the greater opportunity of remaining suspended.

Effects of Flushing

The conclusions to be reached, therefore, are that as a general rule it is advisable to provide means for flushing pipe sewers when they are laid at flatter gradients than those listed below:

12-in.....1:300	21-in.....1:600
15-in.....1:400	24-in.....1:700
18-in.....1:500	27-in.....1:800
30-in.....1:900	

Between 2,000 and 3,000 gallons at a flush, according to the size of the sewer and provided it is released once or twice every 24 hours, usually suffice. In any event it should be an amount that, when it does come into the sewer, practically fills it at that point. This, because the depth of the flushing wave near its point of origin decreases as it moves downstream to a point at which the depth and velocity are but little affected by the discharge. As an example, one can consider a 12-in. sewer flush by a 1,500-gallon tank through a 10-in. syphon in 1¼ minutes.

On the accompanying chart the upper set of curves relate to such a sewer laid at 1:630. One curve reveals transmission velocity, the other steady-flow velocity. As regards the former, the rate of transmission, at the commencement of the flush and at different distance from the flushing chamber, is that which would give the maximum scouring velocity, assuming the flush to be discharged into an empty sewer. This velocity lasts but a few seconds and its effect reaches but a short distance. In the matter of the steady-flow velocity, during the period when the maximum volume of flushing water is passing at different distances from the flushing chamber, it will be observed that this velocity lasted for a minimum period of 1 min., the period increasing with the distance from the flushing chamber. There is also a third curve which reveals the maximum volume of flushing water in gallons per minute at different distances from the flush chamber. From this curve, the effect of varying the amount of flush water discharged per minute can be determined. The lower set of two curves, in comparison, relates to a 9-in. sewer having a flush of 750 gallons for one minute.

Facts and Conclusions

The principal facts which become apparent from an examination of these curves are that:

(1)—The velocity dies off rapidly at first until it attains a certain value after which the diminution is small. As a result the flush is transmitted over an appreciable distance, probably about one mile.

(2)—With flat gradients, the velocity when the maximum volume of flush water is passing is less than the rate of transmission at the commencement of the flush, the difference gradually decreasing as the gradient decreases until the velocities are identical—such being indicated by the lower graph.

One can conclude, therefore, that the slope of the advancing flush will gradually flatten as the distance from the flushing chamber increases except where the gradient is sufficient to secure a high velocity. It is noticeable, also, how the steady flow velocity is over 3-ft./sec. at a distance of more than 3,400 ft. from the flush chamber. If, therefore, the sewer gradient is reasonably good, though appreciably less than that above set out, a good flush (rapidly discharged) will keep a sewer clean for at least half a mile even though its capacity be considerably in excess of normal dry weather flow requirements. And that, as already indicated, is the main purpose of artificial flushing.

Maximum Flow Gage for Sewers*

The accompanying sketch pictures the type of maximum flow gage, which has been installed in five manholes in the village of Shorewood in Milwaukee County, Wisconsin.

Metcalf and Eddy, in "American Sewerage Practice" (Vol. I), under Maximum Flow Gages, describe a device that is substantially a stick with small vials attached along its length and inserted into a perforated pipe. The level of the mouth of the highest vial found full indicates the height to which the sewage has risen in the manhole. This design, however, has its disadvantages. First, the vials are breakable and entail considerable trouble in replacing. Second, it can not be used where the velocity exceeds eight feet per second.

The improvements in the Shorewood installation are:

First: It is cheap—the entire gage, made by a tinner and ready to install, costs very little.

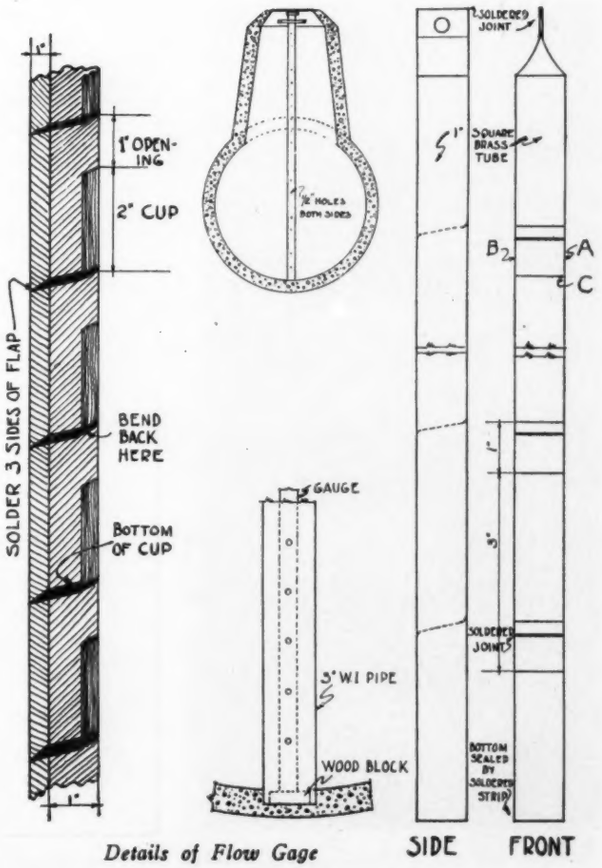
Second: It is not breakable and may be used in sewers regardless of velocity. Being made of brass or copper it is immune to corrosion.

A brief description may be helpful.—This gage is made of one inch (square) brass tubing, with one face (C on sketch) cut through at predetermined spacings. In the Shorewood design it is three inches. Then the corners are ground off on a power grinder to make edges A and B. The resulting flap is bent back and soldered in place to form the bottom of the pocket above. The block of wood is to raise the gage to the elevation of the invert of the sewer. The spacing of the pockets and the width of the mouths may be varied to suit circumstances. A perforated 2 in. W.I. pipe protects the gage.

In practice the gage has proven reliable and has served satisfactorily through several storms when the sewers were surcharged.

Credit for this design belongs to George Dewey Simms, Assistant Village Engineer, Shorewood, Wis.

*Contributed by Julius Lucoff, Milwaukee, Wis.



Details of Flow Gage

TRANSITE PIPE IN DIFFICULT SEWER JOB

By HORACE J. COOK, Engineer and Superintendent
Water and Sewerage District, Auburn, Maine

IN THE spring of 1937, sewage was found to be backing into the basements of a large number of residences in Brunswick, Maine, the home of Bowdoin College. It was, in fact, the area occupied by this institution which was affected.

Upon investigation it appeared that the 12-inch vitrified clay pipe sewer was crushed and entirely plugged. Attempts were being made to remedy the condition by relaying this with a 12-inch cast iron pipe. As the water standing in the trench was considerably above this pipe, it was evident that either this cast iron pipe was plugged or that the grade was such that the water could not flow through it.

Further investigation showed that the 12-inch pipe was too small for the area served. It was found also that the 12-inch iron sewer was out of line horizontally and vertically. Later a hump in the pipe of 3 feet was discovered, which gave an adequate reason for the water standing in the ditch.

When holes were driven to check conditions, it was learned that the grade of the original sewer was from 24 to 28 feet below the surface of the street. The soil was a very fine sand. At the depth of 16 feet water was encountered, which meant that the entire trench must be tightly sheeted to prevent the flow of quicksand. It was also known that the joints in the iron pipe were not tight and that the water and fine sand were filtering into the sewer.

It was decided to lay an entirely new 18-inch line from Pine Street to Harpswell Street, along Bowker Street. An 18-inch pipe of the type used on a 3 per cent grade will carry three times as much water as a 12-inch clay pipe. The grade and depth of the sewer had been determined by the original builders years ago. The sewage was delivered, at a certain depth, at the Junction of Harpswell and Bowker Streets, with its outfall, at a certain depth, at the junction of Pine and Bowker Streets. A straight line between these points was the only grade possible. This gave only a drop of 4 inches in 100 feet.

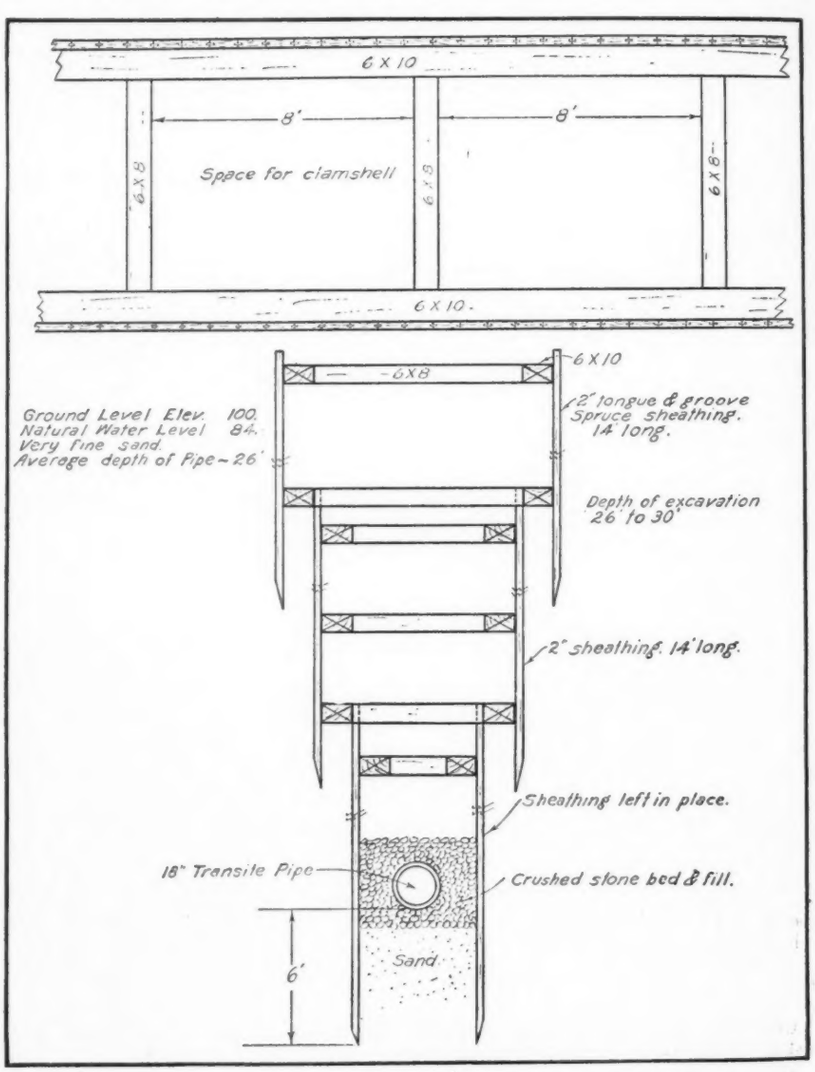
"Transite" Pipe Used

The pipe chosen for the job was "transite" pipe, a product of the Johns-Manville Company. This pipe is being used increasingly in the water works field for distributing water under pressure. As it is constructed of cement and asbestos, it does not lose any carrying capacity due to incrustation and has a very high crushing strength. The trench was entirely too deep for the use of vitrified clay pipe unless it was encased in concrete. The Johns-Manville Company guaranteed that this pipe would stand the pressure and that asphaltic joints made according to their instructions would not leak.

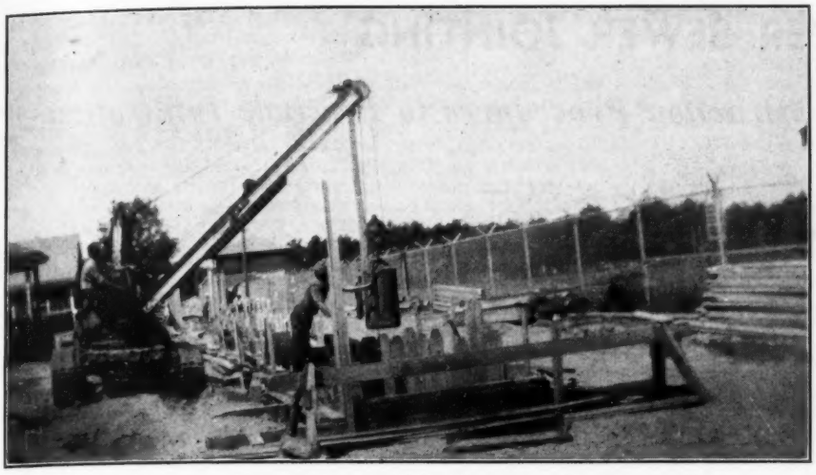
Sheeting Method

The accompanying sketch and pictures show the layout of the sheeting. Spruce timbers 6 x 10 inches in size, placed not over four feet center to center, acted as rangers. The braces were 6 x 8 inches with eight feet clearance for a chance for the clam-

The 18" Transite Pipe in Place



Details of Sheeting in Fine Sand Sewer Excavation to 26 ft. Depth



Bucket Used in Deep Excavation Going to 26 ft. Below Street Level

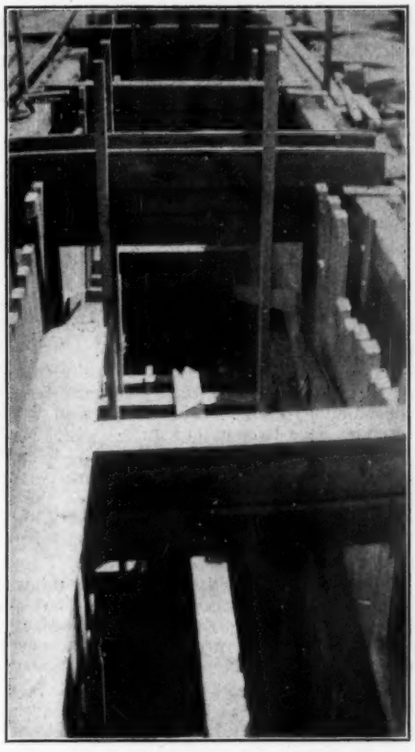
shell bucket. Three sets of sheeting were used, the lower being left in place.

It was found impractical to use the sewer already laid to drain away the water in the trench, as the men working in the trench would stir up the fine sand and the water would carry it into the finished section. Here the grade was so flat that the sand would settle and clog the pipe. It was necessary to pump the water out of the trench into a settling box where the sand was removed. As four cubic yards of sand per day was removed in this manner, it would have been but a short time before the new sewer would have filled if this water and sand had been allowed to enter it.

In the construction of this new sewer, several difficulties were encountered which were lacking in the first work. The drainage and sewage of all the great area above was being emptied into the trench continuously. The old cribbin used in the original construction had been left in place to a great extent. The old pipe, in many cases encased in concrete, had to be broken up with air hammers and removed. There were more buildings to protect, especially the Bowdoin College grandstand. All these features made additional costs which were lacking in the first job. The use of a rock fill under the pipe to give a better foundation than the quicksand and to provide subdrainage, was another added cost.

Costs

In checking the costs of the original sewer in 1903, it was found that the cost to the town was practically $18 per foot.



Sheeting and Bracing
(For details see text)

The first contractor had financial difficulties, and it was finished by another, so the real cost was never known. The repairs since that time had totaled $15 per foot. As labor and materials at that time were about 40 per cent of today's prices, the present cost, in line with the 1903 prices, would be about $45. As a matter of fact, the expense was $32 per foot, or less than the original cost, plus the repairs. Mr. Everett Beedy of Auburne, Maine, was the superintendent in charge of the work, and it is to him that the credit should be given for the efficient way in which the work was handled.

The new transite pipe sewer has been in place now over four years. To date there has been no indication of infiltration of sand or water. Neither has there been any settling in the streets.

NOZZLE REPLACEMENT ON TRICKLING FILTERS

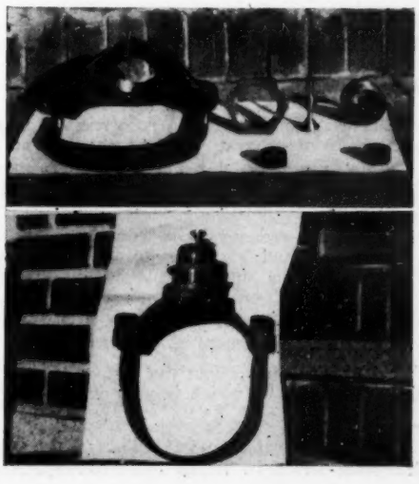
By ROY S. LANPHEAR
Worcester, Mass.

FLUSHING of the lateral distributors of the trickling filters at Worcester is done once each week by removing the end nozzle in each line (several at a time), and allowing the dosing tank siphons to operate once or twice. The threads in the pipe openings, into which the nozzles were screwed, were destroyed after a few months of this routine operation. Cast iron pipe, brass nozzles and a sewage containing strong acid and alkaline industrial waste liquors were also factors in such destruction.

Saddles, with washers and U-bolts, were first used. When the threads in a saddle gave out, a new saddle was installed. This operation proved successful and was used for some time. Additional purchases indicated that while the method was a success, the expense was quite an item in the cost of filter operation. Apparently galvanic corrosion was at the root of the thread wearing difficulty.

A later improvement was the use of a 2½x2-inch brass bushing in the saddle opening. This left the contact of the iron and brass threads undisturbed when removing the nozzles. No difficulty is now experienced and saddles with the bushings have been in use since May 1937. In lots of 200 the cost of the saddles, strap-type U-bolts, and bushings, was 84, 58½ and 47 cents each, respectively.

The accompanying cut shows the several component parts of the successful assembly.



PROPER SEWER JOINTING

And Other Effective Construction Procedures to Preclude Infiltration

By WILLIAM A. GOFF

Consulting Engineer, Philadelphia, Pa.

The method of constructing joints in sewer pipes is directly related to the success or failure of the construction of a sewer system.

Those who are conversant with the many factors in the design of a sewer system, sewage treatment works, and allied units of construction, know the importance of restricting infiltration of the pipe lines to a minimum.

The extent of infiltration is not only indicative of the general character of construction of the work performed. Low infiltration leads to economy in the operation of the system and works and reserves for future use the capacity of the pipe lines and works that otherwise would have been utilized through the conveyance of needless volumes of ground water.

The effort put forth today in the treatment of sewage, which in a majority of cases requires initial pumping and in many instances secondary pumping, emphasizes the need of tighter sewers. It is readily discernible that every drop of water that enters the lines and is pumped and treated, invoives costs.

There are unquestionably numerous factors directly related to the infiltration of pipe lines, but there can be no question that the most important factor entering into this particular phase of construction is the method of constructing the joints.

In the established practice of awarding contracts to the lowest bidder, there is little or no definite assurance of the qualifications of the men who will do the work. Under prevailing conditions in public contracts a contractor is not selected on his record of satisfactory construction performance, but rather upon the price bid. While a contractor himself may be most willing to perform his contract satisfactorily, it is actually the men who work in the trench who are the keystone of performance.

The Importance of Exacting Specifications.

To afford these men the opportunity of producing satisfactory results, the engineer must of necessity know the conditions under which these men are to work, and provide in his specifications such methods of construction as will enable these men to perform their work in a satisfactory manner. In addition, the contractor must cooperate with all of his facilities in an endeavor to produce the results desired. It is this thought that I have uppermost in my mind when planning and designing a system of sewers, for I fully realize that unless the men who actually do the work are provided with a suitable method of construction, the finished product will not be satisfactory regardless of their efforts.

I have found that where a large portion of the sewer joints are to be under three or four feet head of water, that the dewatering of the trenches by the method of well points, has been the most successful means of providing favorable working conditions for the men making the joints in the trench.

Value of Trench Dewatering by Well Points.

This pre-draining of the construction area prior to the commencement of excavation does three things:

First—It provides the contractor a dry ditch in which to work and also gives the inspector a better chance to inspect the joints.

Second—It reduces by a considerable amount the need for sheeting and shoring. In the majority of cases of predraining the sides of the bank will remain standing, even in sand, with only skeleton bracing.

Third—It eliminates all needs for special construction, such as concrete encasement or cast iron sewer.

All of these things affect the cost and incidentally help to create tight joints, all of which is very important.

From Proceedings of the Twelfth Annual Conference of the Maryland-Delaware Water and Sewerage Ass'n.

After affording favorable working conditions for the men in the trench, the next step is to provide a suitable joining material and the method of its construction to obtain the desired objective.

The Most Effective Joint.

Outstanding are the bituminous joints, both hot and cold. Basically they are composed of coal tar or asphalt, mixed with powdered inert materials and either poured into the joint while hot and allowed to cool, or preformed joints inserted in the joint space and pushed in place when the pipes are assembled.

Jointing with hot poured compounds has the advantage of completely filling the annular joint space, more permanent adhesion to the pipe sides, and a degree of resiliency which will permit slight movements of the pipe line.

Preformed joints have made their appearance on the market and have been used with various degrees of success. One preformed joint, consisting of collars of felt impregnated with these asphalt compounds, made in sizes to fit the commercial pipe sizes, is slipped over the spigot end of the pipe and forced along with the pipe by means of a mechanical jack, into the bell of the receiving pipe; the natural resiliency of the preformed joint distorting to fit the shape of the bell and spigot. Another preformed joint which has been used with good results is made by the use of metal dies clamped in the bell and around the spigot of pipes and poured with hot compound prior to lowering the pipe into the trench. At the time of assembly the two preformed collars are painted with a solvent and pushed together the solvent causing the collars to fuse and thus form the joint.

Jointing Experience

The type of joint which I have been using for the past seven years is the result of numerous experiments and actual field tests, and consists of the following:

Oakum packing of approximately 1-inch in depth.

A hot bituminous joint of approximately 1½ inch in depth, and an outside cement mortar fillet wrapped in a muslin cloth tied tightly in place.

Such a joint sounds complicated, but my experience shows that after the ditch-men become experienced, the joint can be made rapidly and consistently perfect. Perhaps this joint does add a few cents to the per foot cost of the sewer, but what of that. The owner is buying a sewerage system and he wants a good one. It is distinctly worth while to avoid infiltration and all will agree that there is only one time to get tight construction and that is when the sewer is built. Any small initial increased cost of construction is soon compensated by the economies possible where the infiltration is negligible.

Laying Specifications.

In the construction of the joint I specify, the pipe be laid by two men, one holding the spigot end of the pipe in a "U" shaped sling consisting of perhaps two strands of jute at the end of the pipe while the other man pushes the pipe home from the bell end. After the pipe is home the front man wraps the oakum over the pipe and pushes it in place with a caulking iron, so as to provide proper space for the bitumen, while the back man tests the pipe for elevation with a grade rod from the line above and checks for line by a plumb bob from the same line, and makes such adjustments as necessary. He then moves forward, checks the subgrade for elevation and excavates bell and a length four inches longer than the circumference of the last pipe laid and determines if it is free of water. The next pipe is then handed down into the ditch and laid as before. The top man, before handing the pipe down, ties on the bell end of each pipe a piece of muslin with a width of six inches greater than that of the bell and a length four inches longer than the circumference of the bell. This cloth has been torn to provide tie strings at each of the four corners. Another man follows behind and places around each bell a runner fastened

with a clamp at the top. Into this runner mouth he pours the hot joint compound, being careful to keep runner filled at the top and see that there is no leak at bottom or sides.

When cold, the runner is removed and the muslin band pulled out under the joint and completely filled with a cement-sand mortar (1:2) to form a 45° fillet around the outside of the bituminous joint. The mortar is pushed under the pipe to fill the band and the cloth band is then pulled tightly up and tied with the two remaining strings across the top of the pipe. The joint man then encircles the pipe with his hands and makes sure that the muslin band is completely packed with mortar, *especially at the bottom,* and that the band is tight. He then draws his hands upward, pressing the joint and dresses the top. Of course the mortar must be fairly stiff. It is not as complicated as it sounds, and contractors who have worked under me are generally enthusiastic after their men get the swing. It makes a *good* joint. The men know it. The inspector can check it. The contractor can see it and knows that future infiltration trouble is ended.

Features of This Joint.

The joint itself is correct. The oakum prevents the bitumen from getting into the pipe. The runner forms a tight channel for the bitumen which fills the annular space, adheres to the pipe surface and forms a tight joint. The bitumen can be readily inspected when the runner is removed. The cement collar reinforces the bitumen and provides maximum reinforcement where there is the greatest chance of a slip in the bitumen joint. That is as always, at the bottom. If by accident there should be a poorly poured bitumen joint the tightly packed cement mortar fillet will be forced into the hole and the rag will hold it there while the mortar hardens. The mortar fillets tends to give rigidity to the joint. The rag prevents backfill on a freshly made joint from disturbing the joint.

Results.

Results in the use of this joint have proven remarkably successful. Nowhere have contractors failed to meet the severe infiltration limitations I have set up in my specifications where I have used this joint.

In Harrington, Delaware, for instance, we constructed 8.08 miles of sewers, of which about fifty per cent was wet trench with an infiltration only 6.6% of the allowable.

In Berlin, Maryland, we constructed 7.97 miles of sewer of which 30% was wet trench with an infiltration only 7% of the allowable.

Other Records	Miles	Percent of allowable
Spring City, Pa.	9.59	27
Florence, N. J.	12.14	20
Conshohocken, Pa.	25.08	3
Georgetown, Del.	8.36	21
Clarks Summit, Pa.	18.99	68

Think of it, even in the last case we have a 19 mile system with a total infiltration of only 3,790 gallons a day, or less than three gallons per minute. Then consider that a ¼-inch hole under a two foot head of water will give a flow over one-half gallon per minute.

The infiltration limits I specify are as follows:

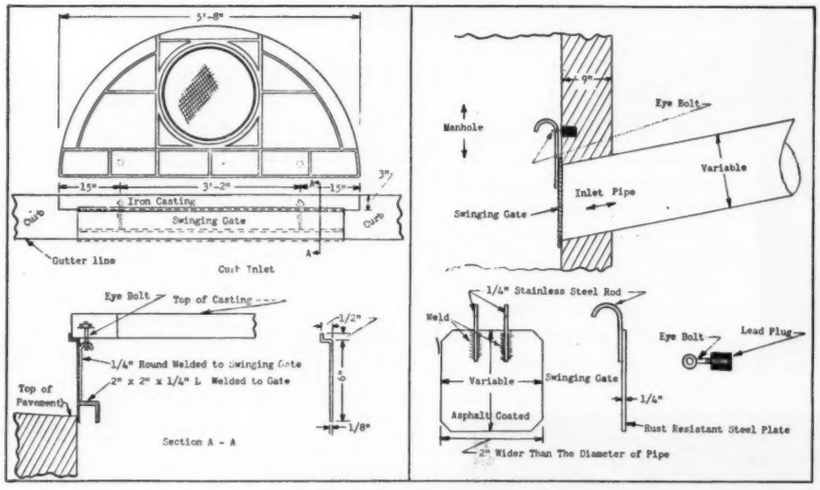
Size of T. C. Pipe-inches	Gallons-per mile in 24 Hours
5— 6	4,000
8	5,000
10	6,300
12	7,500
15	9,500
18—36	15,000

In the above mentioned list of recent jobs well points were used on Harrington, Delaware; Berlin, Maryland; Florence, New Jersey, and Georgetown, Delaware. In all of these instances quicksand was met and in no case did we use any special construction method.

Backfilling.

In backfilling the trench care must be taken to use only fine soft earth around the pipe in order to minimize the possibility of cracking the pipe. This initial backfill should be placed equally on both sides of the sewer to prevent dislodging and be carried at least one foot above the top of the pipe and carefully tamped to insure equal solid side foundation around the sewer pipe.

SEWER ODOR TRAPS FOR MANHOLES AND INLETS



Cincinnati Sewer Odor Traps

To hold in sewer gases and prevent the emanation of objectionable sewer odors from storm inlets to combined sewers and sewer manholes the here sketched swinging flap-gate arrangement has been designed and installed in Cincinnati by the Department of Public Works.

The trap for inlets (left) consists of a swing gate of ⅛ in. metal, fabricated and installed as sketched. The gate flap, reinforced and weighted with an angle iron welded across the bottom, opens inward under force of storm water and returns to closed position thereafter.

The trap for manholes consists of swing gates on all inlet sewers entering the manhole (right) and are apparently intended to preclude odors and gas from working back up-sewer rather than to prevent odors emanating at the top of the manholes so equipped. Naturally, the latter source of sewer odors can be corrected by plugging what appear to be of more hazard and detriment than of help—the vent holes in manhole lids—and employing rattle preventing "Tapax," or its equivalent, for sealing the space between the lid and the manhole frame.

It will be noted that non-corrodible metal and bituminous coating are used to preclude corrosion of the flap gates and hinges employed in manholes.

THE JEFFREY MANUFACTURING COMPANY

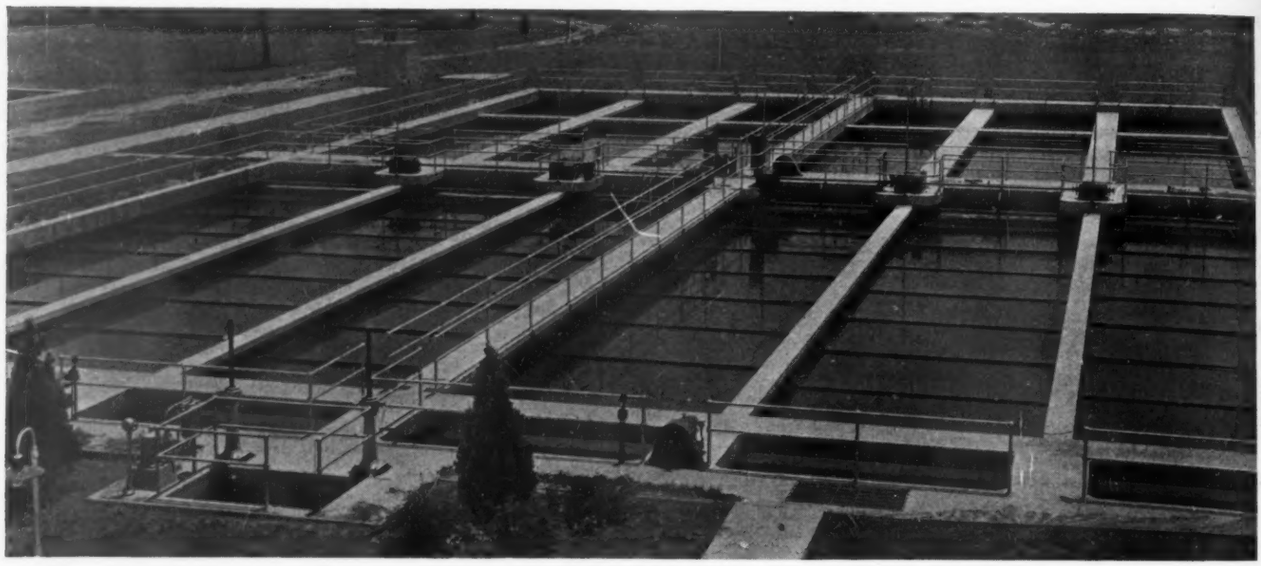
SANITARY ENGINEERING DIVISION

996-99 North Fourth Street, Columbus, Ohio

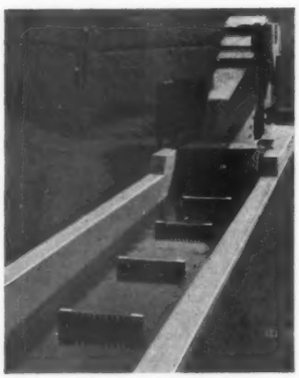
Baltimore	Buffalo	Cleveland		Harlan	Milwaukee	Pittsburgh
Birmingham	Chicago	Denver		Houston	New York	Scranton
Boston	Cincinnati	Detroit		Huntington	Philadelphia	St. Louis
						Salt Lake City

Jeffrey Mfg. Co., Ltd. of Canada—Head Office and Works: Montreal

PRODUCTS: Sludge Collectors Bar Screens Scum Collectors Grit Collectors Grit Washers Floctrols Chemical Feeders Sewage Screenings Grinders Garbage Grinders Dried Sludge Grinders Sludge Elevators Conveying and Elevating Equipment

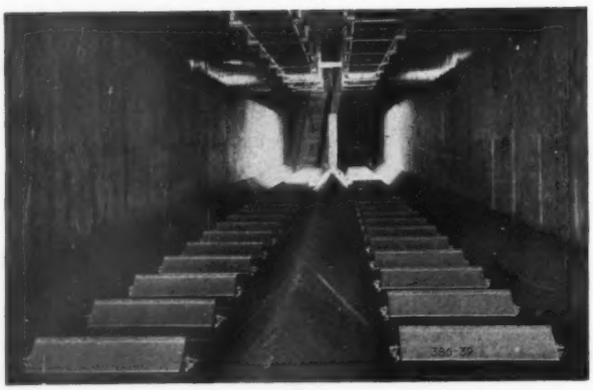


Typical installation (above) of Jeffrey Sewage Treatment Plant showing rectangular tank design. Jeffrey collectors will remove sewage sludge effectively and economically.



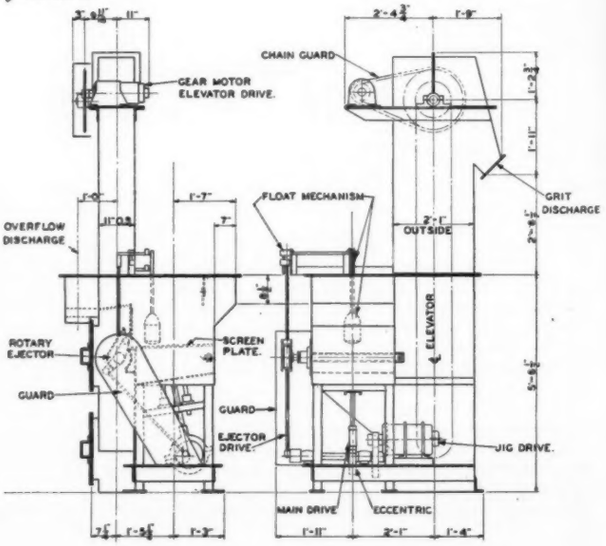
GRIT COLLECTORS *(Patented)*

Three types for grit channel mechanism; scraper, V-bucket and a combination of the two. Scraper type shown left—V-bucket type with horizontal and vertical runs below. Latter type is ideal where space is limited or where grit must be carried to a considerable height.



GRIT WASHERS **(Patented)**

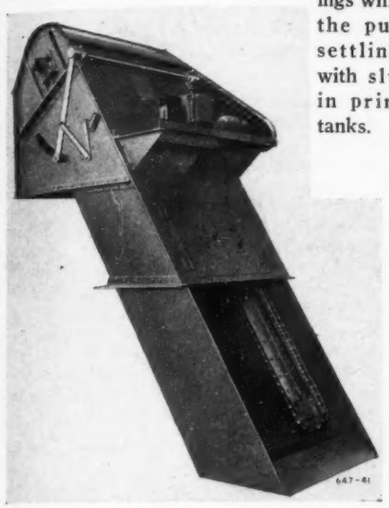
The Jeffrey Jigrit method of washing grit has been proved —will remove from 70% to 90% of putrescible solids, the washed grit being free from objectionable odors or unsightly appearance. Two sizes with capacities from 1 ton to 4 tons per hour. Drawing below is of the No. 4 JIGRIT.

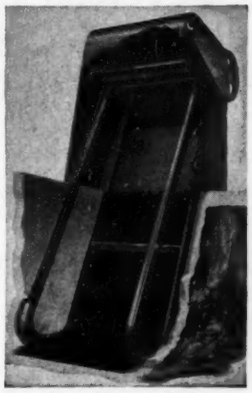


THE JEFFREY MANUFACTURING COMPANY

SCREENS AND GRINDERS

Efficient apparatus for removal and disposal of sewage screenings—Jeffrey combination Screen and Grinder. Takes care of disposal of sewage screenings, which are removed by grinding to a pulp and returning to the sewage. Pulped screenings will pass the pumps, settling out with sludge in primary tanks.



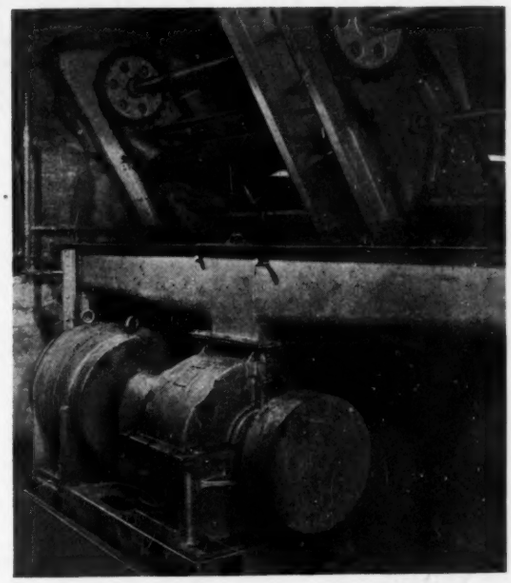


Jeffrey inclined bar screens—heavy duty type (above) for handling flow up to 300 M. G. D. Screen on the left was designed for small plants. It is factory assembled to eliminate field erection cost. Will handle maximum flow of approximately 12 M. G. D.

Jeffrey screens are cleaned by rake mechanism, teeth passing between the bars as rake moves upward. Operation is entirely automatic and controlled electrically.

Reg. U. S. JM *Pat. Off.*

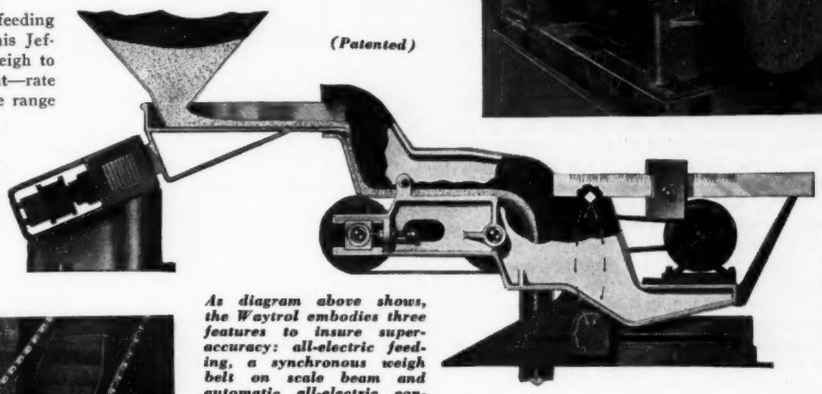
Installation view below shows two mechanically-cleaned bar screens and one screenings grinder in a large sewage treatment plant. Screens operate on automatic time control—screenings hand fed to grinder. This makes an ideal combination for removal and disposal of screenings.



JEFFREY WAYTROLS

Continuous and accurate weigh-feeding of dry chemicals assured with this Jeffrey Waytrol. It will feed and weigh to within 1% of the required amount—rate of feed can be varied over a wide range by merely turning a knob. Maximum accuracy and response with this versatile unit—beam does no work except weigh. Once set at a given rate, the feeder will automatically maintain it, regardless of density or moisture change.

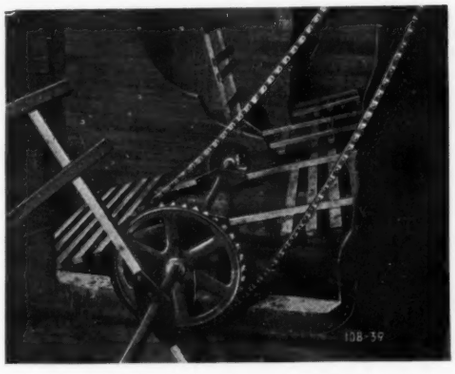
(Patented)



As diagram above shows, the Waytrol embodies three features to insure super-accuracy: all-electric feeding, a synchronous weigh belt on scale beam and automatic all-electric control, sensitised through "electric brain."

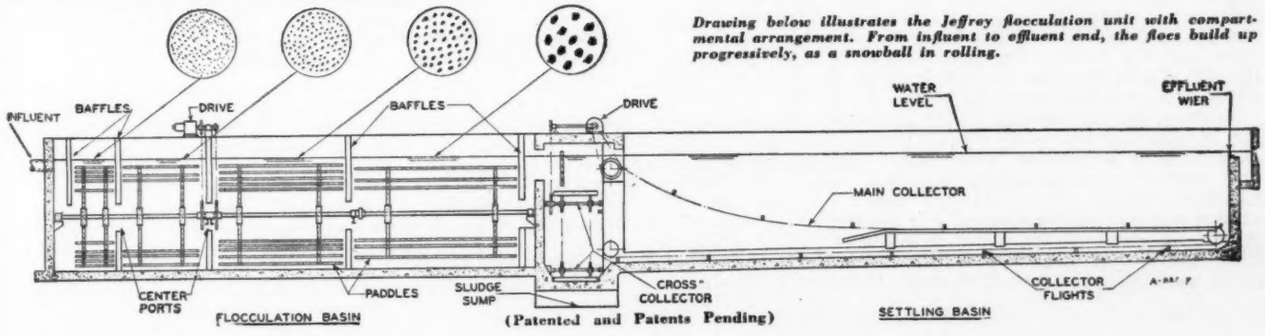
Jeffrey sewage and water treatment equipment has been installed in some of the largest plants in the country—municipal as well as Victory projects, cantonments, air bases, etc. Write for complete engineering information.

(Patented)



JEFFREY "FLOCTROL"—a new process for pre-clarification of turbid waters. While using a minimum of chemical coagulant, it conditions water to obtain substantially complete removal of solids in sedimentation basin. Can be used for treating sewage and waste water, water softening and industrial processing. Low first cost—minimum of short circuiting—low chemical cost—tapered mixing—no mechanical adjustments.

Drawing below illustrates the Jeffrey flocculation unit with compartmental arrangement. From influent to effluent end, the floes build up progressively, as a snowball in rolling.



(Patented and Patents Pending)

AN IMPROVED METHOD OF VELOCITY CONTROL IN GRIT CHAMBERS

By RALPH J. BUSHEE, Designing Engineer
Chas. W. Cole & Son, South Bend, Ind.

Part I—Method of Velocity Control

THE problem of designing a grit chamber with a control section that will give a constant velocity at all flows is essentially that of making the shape of the depth versus cross-sectional area curve of the grit chamber fit the depth versus quantity/velocity curve of the control section. The earlier approach to this problem consisted in the development of the so-called proportional weir, which had a straight line depth-quantity characteristic as is needed with grit chambers of rectangular cross-section. While the velocity control obtained by this method has been satisfactory, there is a disadvantage in that for proper operation of the weir, the entire head in the grit chamber must be lost.

In order to make use of control sections, such as the Parshall and Venturi flumes, which require a smaller loss of head for their operation, Camp[1] and Holmes[2] have proposed that the shape of the grit chamber be adapted to fit the head-quantity curve of the control section. By this method it is possible to reduce the loss of the head to as little as one third of the depth of flow in the grit chamber. The disadvantage of this method is that the resulting cross section is not the most economical one to build, and moreover, it is not well adapted for most mechanical cleaning mechanisms. The slope of the side walls may be quite flat in some cases. Barker[3] has suggested that this last difficulty could be solved by building two or more chambers for one control scetion.

A Proposed Method

There is, however, a third solution to this problem which makes it possible to use a grit chamber with a rectangular cross section in conjunction with a flume, or any other control section for that matter, and still get a velocity which is very close to that desired over a wide range of flows.

This method consists essentially in determining the relationships so that the straight line depth versus cross-sectional area curve of the rectangular grit chamber lies as closely as possible to the depth versus quantity/velocity curve of the control section, over the range of flows being considered. To accomplish this, two relationships must be determined; first, the ratio of the width of the grit chamber to the width of the control section which gives the closest average slope of the two curves; and secondly, the relative elevations of the bottoms of the control section and of the grit chamber which result in the closest position of the two curves. The determination of these two relationships can best be made graphically and the curves of Fig. 1 are used for the solution with a free-flowing venturi flume. It will be understood that the method is perfectly general and can be used for any type of control section for which a curve can be drawn.

A Specific Example

The formula for the flow through a rectangular free-flowing Venturi flume is

$$(1)\quad Q \equiv 3.09\ b\ H^{3/2}$$

where "Q" is the flow in second feet, "b" is the width of the flume in feet, and "H" is the total energy head (depth plus velocity head) above the flume.

The middle curve in Fig. 1 is for the above formula with $b = 1.0$. In order to be able to determine the velocity limits within which we are working, curves of 0.95 Q and 1.05 Q are also shown.

As an example, assume a grit chamber 4 feet wide with a maximum capacity of 8 m.g.d. or 12 sec.-ft. At 1 foot per second velocity the depth at maximum flow would be 3 feet. Lay a triangle tangent to the lower curve and at such an angle that the difference in ordinates between the point where the edge of the triangle cuts the OY axis and the point where it intersects the upper curve is 3 feet. The point where the straight edge cuts the OY axis, in this case 0.62 feet, is the distance that the bottom of the flume must be below the bottom of the grit chamber.

To determine the required width of the control section, draw a line through the zero point parallel to the above line. A point on this line is $E = 1.0$ and $Q/b = 6.7$. Thus with a foot in the grit chamber, corresponding to 1.62 feet total energy head on the flume, a flume 1 foot wide will pass 6.7 sec.-ft. Since the amount required for the assumed grit chamber 4 feet wide is 4.0 sec.-ft., the width of the flume should be 4.0/6.7 of 1 foot or 0.597 foot, or 7.15 inches. It will be noted that between depths of 0.4 and 3.0 feet in the grit chamber (heads of 1.0 and 3.6 on the flume), corresponding to flows between 1.1 and 8.0 m.g.d., the theoretical velocity through the grit chamber will be between 0.95 and 1.05 feet per second. This range of flows, with the maximum of seven times the minimum, is sufficient for most conditions.

Correction for Fillets

Most grit chambers have fillets at the bottom. With hand cleaned grit chambers this allows the cross-baffles, or other means of demarcation of the grit storage space, to be removed for the manual cleaning of the chambers. With mechanically cleaned chambers it allows the installation of cleaning devices with scrapers or buckets shorter than the width of the chamber. Where such sloping sections are installed it is merely necessary to maintain the total cross sectional area of the grit chamber below the top of the fillets.

Thus in Fig. 2 the areas omitted (1 + 2) must be equal to (3), the area added. The cross-sectional area of the original grit chamber below the top of the proposed fillets is $b \times d$. The area of the new section below the same line is $ab - ac = a(b - c)$. Equating these and solving for $(a - d)$, which is the distance that the bottom of the new section must be lowered, we obtain

$$(a - d) = \frac{ac}{b}$$

Returning to the example employed, suppose that it is desired to install fillets 0.75 foot wide (c) and 1.0 high (a). Then it will be necessary to lower the bottom of the grit chamber in respect to the bottom of the flume by $\frac{0.75 \times 1.0}{4.0} = 0.19$ foot. And the bottom of the control section will be $0.62 - 0.19 = 0.43$ foot below the bottom of the grit chamber.

After the control section has been determined, it is well to check the design computations to see what velocity may be expected.

Table 1
Velocities Through Grit Chamber

Flume		Grit Chamber		
Total Head, Ft.	Flow, Sec.-Ft.	Water Depth, Ft.	Cross Section Area Sq. Ft.	Velocity, Ft./Sec.
0.93	1.79	0.50	1.44	1.24
1.43	3.16	1.0	3.25	0.97
1.93	5.09	1.5	5.25	0.97
2.43	7.05	2.0	7.25	0.97
2.93	9.32	2.5	9.25	1.01
3.43	11.9	3.0	11.25	1.03

Note that the introduction of fillets has increased the velocity at the 0.5-foot depth in the grit chamber. Without fillets the velocity at this depth would have been 1.08 feet per second. However, the results are close enough for this case, and in cases where they are not, the design can usually be improved with a little cut and try.

Part II—The Control Section

Sections Considered

Theoretically, any control section for which a head flow curve can be drawn can be used with the above method. From the standpoint of construction, however, the Parshall and the rectangular Venturi flumes offer advantages.

The Parshall flume would at first sight appear to be the ideal section to use, as it has a solid background of experimental data, and is made with plane surfaces which permit of easy construction. Unfortunately, however, the maximum depths commonly used in the design of grit chambers are beyond the range of the experimental data available for Parshall flumes. There is also some difficulty in interpolating smaller sizes of Parshall flumes which are of somewhat different shapes. This difficulty could be solved by making the width of the grit chamber correspond to that of one of the standard flumes.

If a Parshall flume is used, it is to be noted that the head

given in the formula is not the total head above the flume, as in some cases the velocity head at the point of measurement is a considerable proportion of the total head.

Free Flowing Venturi Flume

Where there is sufficient loss through a Venturi flume to allow it to occur, the quantity passed by the flume will be the maximum possible for the total head available. The flume is then said to be free flowing and formula (1) will apply. In general, free flowing conditions may be assumed in a Venturi flume when the loss of head is not less than one-third of the total head above the flume. The formula is a rational one and is obtained as follows:

$$(2)\ Q = b d_t V_t$$

$$(3)\ d_t + \frac{V_t^2}{2g} = H$$

(by Bernoulli's theorum neglecting friction)

Where Q, H and b are as previously given, and d_t and V_t are depth and velocity respectively at throat of flume.

Solve for V_t in (3); substitute it in (2); solve for dQ/dd_t, and equating it to zero, derive $d_t = \frac{2H}{3}$

as the condition giving the maximum value of Q.

Substituting 2/3 for d_t in (2) and (3), solving for V_t in (3) and substituting in (2) gives

$$(4)\ Q = \frac{2}{3}\left(\frac{2g}{3}\right)^{1/2} b H^{3/2} = 3.09\, b\, H^{3/2}$$

It is reasonable to suppose that the shortest possible transition section ahead of the throat which would avoid a too abrupt change in flow conditions would be the one in which the slope of the water surface was uniform.

In addition to the definiations given above, let "mb" equal the width at a section at a distance of "nL" above the throat, "h" the water depth at this section, and "L" the length of the section between the grit chamber and the throat of the flume (Fig. 3).

$$\text{Then } (5)\ h = 2/3H + 1/3H\frac{nL}{L}$$

$$= \frac{H}{3}(2 + n)$$

$$(6)\ H = h + \frac{v^2}{2g}$$

$$(7)\ V^2 = \frac{Q^2}{m^2 b^2 h^2}$$

and (4) $Q = 2/3\ (2/3g)^{1/2} b H^{3/2}$

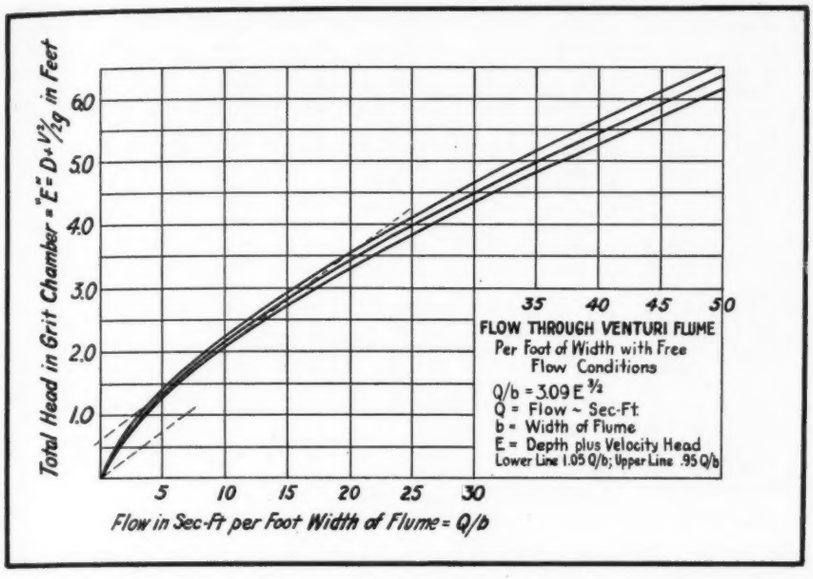


Fig. 1—Flows per Foot of Width of The Venturi Flume for Various Heads.

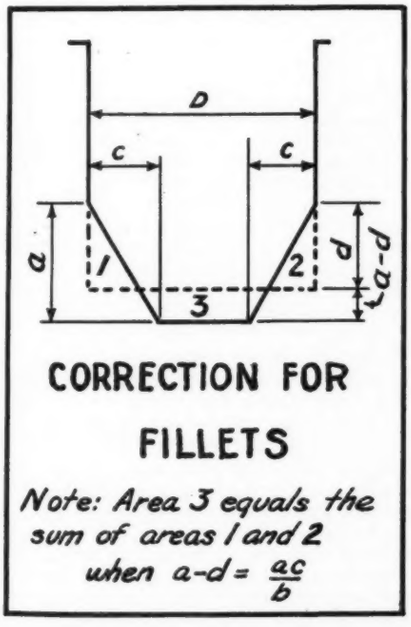


Fig. 2—Method of Correcting for Fillets in Design.

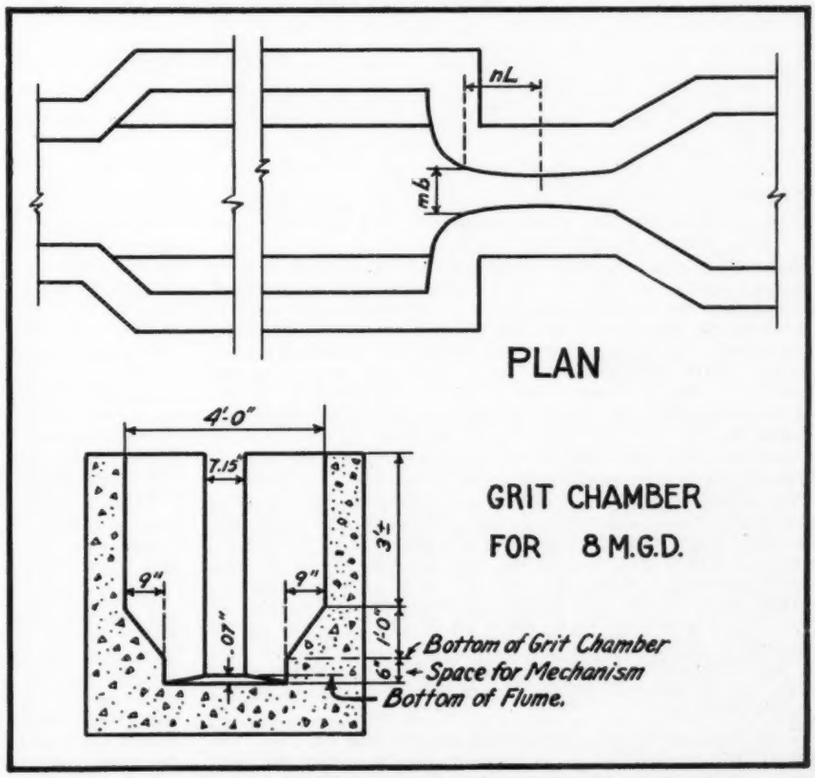


Fig. 3—The Completed Design for the 8 M.G.D. Example Selected.

Substitute these values of h, V and Q in equation (6) and the equation reduces to

$$(8)\ m = \frac{2}{(1-n)^{1/2}(2+n)}$$

The following table gives the relationship expressed in the above formula:

TABLE 2

Factors for Designing a Flume with Uniform Slope of Water Surface

n = Factor for Distance Above Throat	M = Factor for Width of Section
0	1.0
0.1	1.005
0.2	1.02
0.3	1.04
0.4	1.08
0.5	1.13
0.6	1.22
0.7	1.35
0.8	1.60
0.9	2.18
1.0	∞

Returning to the example employed, suppose we assume that the length of the transition section will be the equal to two-thirds of the maximum assumed depth of flow, or 24 inches. This will correspond to a maximum water surface slope of 3 to 1, as the depth at the throat will be two-thirds the head in the grit chamber. Also assume a length of throat of 0.2 of the depth, or 7.2 inches. Assume the return section with the same 3 to 1 surface slope. Then, since the minimum loss of head that we have assumed is equal to the velocity head at the throat section, it does not appear necessary to be concerned with the recovery of this velocity head. Make the return section 18 inches long, which allows for a theoretical recovery of 50 per cent of the velocity head. The total length of the control section is then 24 + 7.2 + 18 or 49.2 inches. Using the above table and the established throat width of 7.15 inches, we obtain a flume of the following shape. The width has been divided by 0.97 to allow for friction loss ahead of the throat.

TABLE 3

Design of Control Section

Distance from Grit Chamber, Ins.	Factor n	Factor m	Width of Section = 7.15 m/.97 Ins.
2.4	0.9	2.18	16.2
4.8	0.8	1.60	11.8
7.2	0.7	1.35	9.9
9.6	0.6	1.22	9.0
12.0	0.5	1.13	8.3
14.4	0.4	1.08	7.9
16.8	0.3	1.04	7.7
19.2	0.2	1.02	7.5
21.6	0.1	1.005	7.4
24.0	0.0	1.0	7.4
27.6	0.0	1.0	7.4
31.2	0.0	1.0	7.4
34.8	0.1	1.005	7.4
38.4	0.2	1.02	7.5
42.0	0.3	1.04	7.7
45.6	0.4	1.08	8.0
49.2	0.5	1.13	8.3

Figure 3 shows the outline of the finished design. It is, of course, not essential that the flume be made with curved sides as shown. This design appears to make for the shortest possible length of control section. If straight sides are used, the approach section ahead of the throat should be longer. It is necessary that the throat be of sufficient length so that the free-flowing condition is well established.

References

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2. Holmes Water Works & Sewerage, May, 1933.
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"DRY CLEANING" AIR DIFFUSER PLATES

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Associate Editor WATER WORKS AND SEWAGE.

EVERY once in a while someone does something that makes one stop and wonder why it has never been done before. Or, if ever done, why he has not heard of it.

Maybe you have been in Southern California when, due to "unusual weather conditions" the winter temperature drops below freezing and the citrus growers start the orchard smudge-pots to warm up the whole outdoors and keep the crops from freezing. If you have, you may recollect that upon such occasions the air in the orchard area is so filled with thick, oily smoke that one cannot see a hundred feet. This winter has been such a one and for a number of days early this month (January) millions of gallons of oil have been burned in the smudge-pots.

Now this may not seem to have anything to do with sewage disposal, but strange enough it does have.

The city of Ontario lies right in the heart of the citrus grove area and, in consequence, was encompassed in a dense smoke fog for some time. During this period the operator of the Ontario activated sludge plant noticed that the pressure on the air lines was steadily increasing at the blowers. Attributing it to the oily carbon in the air, as most likely responsible for the clogging of the diffuser plates, he made every effort to cleanse the air by straining it through several thicknesses of cloth over the air inlet to the blowers. The cloths were changed frequently but to no avail. And, pressures at the blower mounted from 5 to 7½ pounds over night.

Obviously the diffuser plates, which had operated for more than a year with no building up of pressure, had to be cleaned. The finely divided carbon and oil in the smoke had doubtless spread quite uniformly through the plate pores. The orthodox manner of cleaning would have been to remove the plates and clean them up with a solvent and, if not successful, burn out the volatile materials, possibly. The city engineer had other ideas, however, and instead of bringing the plates to the solvent the solvent was taken to the plates. A scheme for injecting the solvent into the air stream from the blowers was put into operation.

What was actually done was to slowly pump "Aviation" grade of gasoline into the airline and beyond the blower. Two gallons of gasoline was fed into the pipe slowly during a 24-hour period. It did the job all right, because during this period pressures dropped back to normal and the trouble was completely cured. So far, there has been no injurious effect upon the quality of the plant effluent or the behavior of the sludge.

This struck the writer as being a most unique method of overcoming a serious difficulty. Mr. Austin Burt, Ontario's city engineer was "the brains" behind this "solvent-solved situation"; and H. M. Ely, as chief operator of the plant, was "the brawn."

In his latest advice to the writer the "inventor" of diffuser dry cleaning states: "We have had to apply our gasoline remedy to the diffuser plates *seven* different times during the more than two weeks of smudge conditions. Each time the pressure was brought back to normal, and thus far we have been unable to detect any serious consequences in the operation of the plant. Altogether, we used seven and one-half gallons of aviation gasoline at the total cost of only $1.16 and feel pretty good at saving the trouble and cost of emptying the tanks, removing and cleaning the plates."

SEWAGE AND SLUDGE PUMPING

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Part I—Sewage Pumping

During the past several years a very marked improvement has been made in the methods of pumping sewage and sewage sludge, and special pumps have been developed for this service. Only a few years ago, however, practically all sewage was lifted with pumps designed primarily for handling water.

The centrifugal dredging pump driven either by a steam engine or an electric motor was used with a fair degree of success at many stations. While this pump would handle sand and gravel satisfactorily, rags would wrap themselves around the impeller and necessitate frequent cleaning of the pump either through hand holes in the volute or by the removal of the side of the case. It was not very efficient and the head was limited. The smaller and higher speed centrifugal pump, used successfully for pumping water, gave more trouble, due to clogging, when used for pumping sewage, than the dredging pump.

Reciprocating pumps were used in many cases. These pumps clogged about as easily as the centrifugal pumps; and, if there were any sand or grit in the sewage, gave trouble due to the scoring of cylinders. At one or two large stations the crank and fly wheel pump was used and operated satisfactorily principally because of its large size. The ordinary duplex steam pump served in a few cases. The single acting triplex pump, equipped with ball valves, although not entirely free from clogging, proved to be the most satisfactory of the reciprocating pumps and was used, and is still being used, successfully for pumping both sewage and sludge. Its cost is, however, greater than that of a centrifugal pump and it is rather noisy. It is worth noting that the design of the most modern reciprocating sludge pumps have apparently been copied from the old single acting triplex pump.

At almost all of the old pumping stations the sewage was passed through bar or mesh screens to remove the rags and other solids from it before it reached the pumps. The cleaning of the screens always proved a laborious and unpleasant task, and did not entirely do away with the necessity of cleaning the pumps.

The Pneumatic Ejector

In order to eliminate the trouble of cleaning screens and pumps, the pneumatic or compressed air ejector was developed. This device, which was first used about fifty years ago, operates by allowing the sewage to flow into an iron or steel chamber and, when the chamber is full, automatically admits compressed air above the sewage thus forcing it out through the discharge line. The mechanism operates very successfully, and stories are told of ejectors having been lost for several years and when rediscovered were found to be operating satisfactorily. It requires, however, air compressors, air tanks, and other appurtenances which make the first cost and also the maintenance expensive. In addition to this, the efficiency is very low. The overall or wire to water efficiency when the compressors are operated by electricity vary generally from 10 to 20 per cent. At present, due to the improvements in the design of centrifugal pumps, ejectors are being used less and less except in the very small stations or for sludge and screenings handling.

Pump Impellers

The improvement in the centrifugal sewage pumps has been largely in the design of the impellers or runners. There are, in general, two types of pump impellers, the open and the closed. The open impeller gives larger water ways with the same size casing, but solids clog between the impeller and the casing and rags wrap around the impeller blades. Increasing the clearances to reduce clogging, of course, reduces the efficiency and does not prevent rags from stopping the flow. Open impellers, generally with only two blades, serve well in small sump pumps and also in sewage pumps of small capacities where a closed impeller small enough to give the desired capacity would not pass solids of any size. In most cases, however, the closed or semi-enclosed impeller is to be preferred.

In the design of closed impellers for handling sewage, the water passages have been made wider than in water pumps, all sharp edges and turns have been carefully avoided, thus reducing the chance of clogging to a minimum. As a general rule pumps with impellers of this type will pass solids having diameters about one pipe size smaller than the size of the pump. One manufacturer is producing a pump with a worm feed to force the solids to the impeller of the pump and also cut and crush them against hard steel bars running longitudinally of the screw case. Pumps of this type are giving satisfactory service in several western stations. A rather unique impeller is used in some English pumps. The impeller is open on the suction side and the blades are considerably wider at the shaft than at their ends. The edges of the blades pass very close to bars set on the inside of the case and macerate the solids entering the pump.

It is customary to require the impellers of the pumps to be made of bronze but with ordinary sewage there seems to be no advantage in the use of bronze as compared with that of cast iron. A few pumps have been installed having cast iron impellers coated with enamel and they are said to be giving satisfactory results. The manufacturers claim a slightly higher efficiency for this impeller than can be obtained with the bare metal impeller.

Submerged Vertical Pumps

For the smaller installations probably the submerged vertical centrifugal pump is the most commonly used. The sump may be made of cast iron or steel or may be of concrete. The motor and pump are both supported on a removable iron cover so that the pump can be lifted out of the sump for cleaning and repairs. Enough head room must, of course, be provided to allow the suction to clear the top of the sump when the pump is lifted out. It is also desirable that the discharge be brought up through the same plate so that it may be easily disconnected. In unheated pump houses, however, it is sometimes impossible to do this without danger of the sewage in the discharge line freezing. Where short separate discharges can be used, freezing can be avoided by omitting the check valves and allowing the sewage in the discharge pipe to flow back into the sump after each discharge. If screens are to be omitted it is usually advisable to provide a pump not smaller than 3 inches in size. Such a pump will have a capacity of from 50 to 300 gallons per minute, depending upon design of the impeller and the speed of the motor.

Float Controls

Sewage pumps are usually automatic in operation and the arrangement of the float control deserves more attention than it generally receives. The float may be connected to the electric switch either by a push rod or by a chain running over pulleys with a counterweight to balance the float. Either method operates satisfactorily if properly arranged. Floats that hang unprotected in the sump are apt to be moved sideways by the motion of the sewage causing the chain or rod to bind, or the rod to bend, making the float inoperative. In some designs the rod has a guide at the bottom to prevent such motion, but if the rod sticks in the guide or leaves the guide its inaccessible location makes it very difficult to repair. The lever float, sometimes used, has generally proved very unsatisfactory for sewage because rags are apt to collect on the lever and prevent its operation. As in the case just mentioned it is generally very difficult to reach such a float to repair or adjust it. The best design is one in which the float is arranged in a tube to guide and protect it and a removable cover plate provided over the tube so that the float can be readily lifted out.

Pumps in Separate Dry Wells

For the larger pump stations, and even in the small stations when the conditions will permit, the installation of the pumps in a separate dry well makes the most satisfactory arrangement. This leaves the pumps and their appurtenances accessible for repairs and adjustment. The pumps may be either vertical or horizontal. The vertical pumps have the advantage of requiring a smaller pit and of keeping all electrical equipment above ground and free from danger of flooding, while on the other hand the horizontal pumps are easier to keep in adjustment and alignment. If the pit is deep, one or more guide bearings will probably be required on the shafts of vertical pumps as it is necessary to divide the shafts into lengths of not more than 8 or 10 feet to prevent vibration. I-beams are usually set across the pit to carry these bearings, but it is often difficult to set these beams so as to get a perfect alignment of the shaft. In order to avoid this difficulty, several manufacturers are building steel lattice frames extending from the motor to the pump. The pump and motor can then be aligned at the factory with very satisfactory results. In some cases the motor, shaft and pump have been attached to a heavy channel, aligned at the factory, and shipped as a unit.

With the pumps in a separate dry well it will usually be necessary to provide some means for removing seepage from the well. This may be done with a separate automatic sump pump, or, if a cheaper installation is desired, a small valved connection may be made from the suction of one of the main pumps to a sump and the sump emptied at intervals by closing the main suction valve and opening the connection to the sump.

Design of Suction Well

The shape of the bottom of the suction or wet well is of considerable importance. If it is left flat, solids will collect in the bottom and ferment giving rise to unsatisfactory conditions. The floor of the wet well should have a steep slope toward the pump suctions.

In some cases where the sewage is warm and contains considerable grease, trouble has been experienced due to the grease congealing on the walls of the well and then breaking loose in large pieces and entering the pumps and clogging them. The openings in the impellers of 4-inch horizontal sewage pumps have been stopped several times by this cause.

Bearings and Glands

There does not appear to be very much choice in regard to the type of bearings used, ball bearings and sleeve bearings seem to serve equally well provided they are properly oiled. Ball bearings are, however, usually provided to take the thrust or to carry the weight of the impeller of a vertical pump. The part of the shaft that passes through the stuffing box should be of bronze or covered with a bronze sleeve otherwise difficulty will be experienced in keeping the packing in condition. This stuffing box is usually provided with a water seal, although grease seals and special devices are sometimes used. In water pumps the water for the seal is usually taken from the volute of the pump. With sewage pumps, however, this is not advisable for the solids in the sewage are apt to clog the small passages and also because the grit in the sewage will reach the packing and cut the pump shaft. To avoid the possibility of the pollution of the clear water with sewage, the water must usually be taken from a constant level tank supplied from the water lines and not directly from the lines themselves. With double suction and open impeller pumps, if there is a suction lift, there will probably be vacuum on the pump side of the stuffing box and the water seal serves to prevent the entrance of air. With end suction pumps, with enclosed or semi-enclosed impellers, there may be a pressure on the pump side of the stuffing box. The water seal then serves to prevent the grit in the sewage from reaching the packing and cutting the shaft. The pressure on the water seal should of course be greater than the sewage pressure.

Centrifugal sewage pumps will operate satisfactorily if set as high as 15 feet or even a little more above the sewage level, but in such cases special priming devices must be provided for the ordinary method of priming, by filling the suction from the discharge line, cannot be used because it is inadvisable to attach a foot valve to the bottom of the suction. While special priming devices can be used, it is better, if possible, to locate the pumps below the level.

Efficiency and Head

The non-clogging centrifugal pumps will generally give over all efficiencies varying from 35 per cent for the smaller sizes to 65 per cent for the larger pumps. The lift of sewage pumps is usually low and most of the pumps are designed for heads under 40 feet but pumps can be obtained that will lift sewage against heads as high as 75 or even 100 feet. Beyond this head two stages are needed, but the ordinary type of multistage pump used for water cannot be used because of the many sharp turns and the narrowness of the water passages. At a station where it was necessary to raise sewage 180 feet, two pumps connected in series on the same base, with the motor between them, have been used successfully. The overall efficiency of the unit was found on test to be 35 per cent.

Hydraulic Characteristics of Centrifugal Pumps

With centrifugal pumps, careful attention must be given to the hydraulic characteristics of the pumps in designing a pumping station, particularly if the discharge line is of any considerable length.

If an engineer desires a pump to deliver 300 gallons per minute against a head of 20 feet he is very apt to add a little to the head for safety and specify that the pump shall deliver 300 gallons a minute against a head of say 21 feet. A typical 4-inch pump will meet these specifications almost exactly, and will require about 2¼ horsepower to operate it and, a 3-horsepower motor will serve satisfactorily. If, after installation, it is found that the actual head is only 18 feet instead of 21 feet, due to some unforeseen condition or due to the fact that the engineer figured his friction for 10 year old pipe and the pipe is actually new pipe, this pump will deliver 600 gallons per minute instead of 300 gallons per minute and will require 3½ horsepower. The 3-horsepower motor will in that case be overloaded. Conditions similar to this occur very frequently and it is best in all cases to require the motor to be of sufficient size to operate the pump without overheating at any head between the maximum and zero.

When two or more pumps are connected to the same discharge line, the reverse condition often occurs. If two pumps, having the characteristics mentioned above, are connected to a single discharge line, one pump operating alone will discharge 300 gallons per minute. When both pumps are put in operation the friction loss in the discharge line will of course increase. With the particular 4-inch pump just mentioned, if this increase is only about 1½ feet (from 21.0 feet to 22.6 feet) the discharge of each pump will be reduced to 200 gallons a minute or the total discharge of the two pumps will be about 400 gallons per minute or only slightly greater than the discharge of one pump. For this reason it is often found desirable, especially with long discharge lines, to arrange the controls so that one pump will shut off entirely and the second pump, designed for a larger capacity and a little higher head, will start when the sewage flow exceeds the capacity of the first pump.

Multispeed motors are sometimes used to meet these conditions but such motors operate only at certain fixed speeds and it is generally difficult to design the pumps to obtain the desired capacities at these motor speeds. Any desired speed may be obtained by using variable speed motors, but if this is done the losses in the resistances greatly reduce the overall efficiency of the pumping equipment.

At the Harlem Valley State Hospital pumping station which contains 8 4-inch 450 gallon per minute pumps, a special arrangement was used. As each additional pump starts the friction loss in the discharge line increases approximately 6 inches. The controlling float and float switches are so arranged that as each additional pump starts the sewage level in the suction well is automatically allowed to rise 6 inches. Thereby, the total head, and consequently the discharge of each pump, always remains the same and has proved a distinct advantage.

Suction Line Difficulties

There are several matters in connection with the arrangement of centrifugal pump suction lines, particularly where there is some suction lift, which, while they seem very simple, have caused engineers and operators considerable trouble. There must be no high point in any suction line where air or sewage gases may accumulate. When the pump is started the accumulated air will expand, flow to the pump, and stop its operation. The reducer at the pump must for this reason always be an eccentric reducer with the flat side up. Connections to a

common suction header must for the same reason be made at the top of the header and not at the center of the side. In some extreme cases it has even been found necessary to place the suction valves horizontally so as to avoid the accumulation of air in the bonnets. Common suctions, that is, single suction lines to which two or more pumps are connected, are a source of trouble in many cases where there is a suction lift, and wherever possible should be avoided. It is often difficult in such cases to make each pump take its share of the load. When one pump is in operation it is often impossible to start the second without shutting down the first and starting both together. A slight leak in the stuffing box of one of the idle pumps will many times admit enough air to interfere with the operation of the other pumps. Even when the pump that is not to be operated is entirely shut off, air will frequently accumulate in the riser from the common suction to that pump and will expand when the other pump or pumps are started and enter them and prevent them from operating.

Part II—Sludge Pumping

Pumps designed for moving or lifting sewage sludge may, in general, be divided into two distinct classes, displacement pumps and centrifugal pumps. Since these two classes differ radically in their design and operation and present entirely different problems for those in charge of them, it is necessary to consider them separately. The advantages and disadvantages of each class are matters which engineers and operators are not entirely agreed upon. Displacement pumps are unquestionably more easily primed than centrifugal pumps when there is a suction lift and will probably handle small quantities of sludge more readily than centrifugal pumps, but beyond this it is doubtful whether the advocates of either class will admit the superiority of the other.

Displacement Pumps

The modern displacement pumps used for handling sludge are always of the single acting reciprocating type, and are usually electric motor driven plunger pumps having one, two or more cylinders. The makes most commonly used generally have cylinders about ten inches in diameter and strokes adjustable from about two to five inches. The pumps are connected to the motors by gears, belts or chains and the motion transmitted to the pistons by walking beams or eccentrics. Each manufacturer apparently believes that the transmission used by him is the best, but in practice there seems to be little difference.

Transmission

Certain matters in connection with the transmission are, however, of importance. If it is desired to have the pump run smoothly it is usually best to keep the speed of the main pump shaft below about thirty-five revolutions per minute. This gives a piston speed of thirty feet a minute or less, a low figure as compared with the usual figures for water pumps; but the strokes of these sludge pumps are very short and the frequency of the reversals seem to be of more importance than the actual piston speed. Pumps of this type are generally arranged so that the length of the stroke can be changed by shifting an eccentric or, which amounts to the same thing, altering the length of the crank arm. This makes it possible to obtain several different rates of discharge, but experience indicates that the use of the shorter strokes is not always entirely satisfactory. The pumps in most cases do not operate as smoothly with the short strokes as with longer ones, the slip is greater and the efficiency lower. The use of multi-speed motors and variable speed transmissions, although more expensive, afford a more satisfactory and efficient method of changing the pump capacities to suit the conditions, and where available should be used in preference to changing the length of the stroke.

Packing

Like all reciprocating pumps the sludge pumps must be packed to prevent leakage between the pistons and the cylinders, and this packing is one of the most frequent causes of trouble in the operation of the pumps. The packing may be either on the cylinder or the piston. Generally it consists of from 4 to 6 rings of ½ inch to ¾ inch packing held in place by an adjustable metal ring or gland. If the packing is too tight, scored pistons or cylinders and broken shear pins will be the result. If the packing is too soft, too loose or improperly placed it will leak. and since the pumps are outside packed this means that the pumps and probably the floor around them will soon be covered with sludge which does not add to the attractiveness of any sewage treatment plant. Opinions differ as to the most satisfactory type of packing. Generally a square braided flax packing serves as well as any. A graphited packing may be desirable to prevent unsatisfactory conditions due to rust where the pumps stand idle for a considerable time. Rawhide packing is satisfactory but does not seem to be necessary except with certain chemicals. The packing must fit and must be properly placed. In cutting the packing it is well to use a template into which a piece of packing exactly the length of one ring can be fitted. In this way each ring will have the same length and the same bevel. The method of oiling the packing varies with the make of the pump. Generally it is found that a fairly heavy oil such as a good grade of cylinder oil gives the best results. Oils known as "500 W" and "Marine Pump Oil" are in common use. A light oil disappears very rapidly. Under continuous operation the packing will usually last about 3 months, but under intermittent operation it may last a year or two. Manufacturers have recently been giving more attention to the finishing of the pistons and cylinders, in some cases grinding them. This has made it easier for operators to keep sludge from leaking between the pistons and cylinders but has not done away with the necessity for careful packing.

Valves

Each cylinder of a reciprocating pump necessarily has an inlet valve and a discharge valve. These valves may be weighted flap valves or ball valves. Each type has its advocates although at present the ball valves seem to be preferred by most operators. Spring loaded poppet valves which operate satisfactorily in water pumps obviously cannot be used for liquids containing an appreciable amount of solids. No mater which type is used the valves will require some attention from the operator. With raw sludge the valves may require cleaning from two to three times a day to two or three times a week. If the pump is handling activated or secondary tank sludge, cleaning will of course be required less frequently. Fibrous material will collect under the hinges or flap valves and rags will accumulate under ball valves holding the valves off their seats and rendering the pump inoperative. Metal flap valves wear at the hinges so that the flap will not seat properly and soon require replacement. Valves of rubber with rubber hinges clog less frequently than metal valves because of their smoother surfaces, but the rubber hinges are inclined to swell and split and it is difficult to turn them back for cleaning. Ball valves are usually of rubber moulded on an iron core. If they are to operate satisfactorily, careful attention must be given to the quality of the rubber, the balance of the valve and the weight of the core. Valves made of a poor quality of rubber will sometimes swell and stick, and cases are on record where the rubber has softened so as to allow the ball to be forced into the piping stopping the pump. The valve must balance or the ball will always seat at the same point and wear rapidly. The weight of the valve must be suitable for the conditions under which it will operate.

Pounding or Knocking

One of the most frequent complaints heard regarding the operation of reciprocating pumps is that they knock or pound. This is due to various causes. Since sludge lines are usually comparatively short, the high water hammer stresses sometimes encountered at water pumping stations are seldom of importance, but the flow of liquid in the suction and discharge lines must be stopped and started with each stroke (single cylinder pump with no air chamber), the valves must close and in doing so strike the seat, and each stroke causes a reversal of stresses in the piston, the crank and the connecting mechanism. These conditions cause pounding which cannot in all cases be entirely eliminated. The subject is too complicated to be discussed in detail here.

The stresses and pounding due to starting and stopping the flow in the discharge line can be generally alleviated by the use of an air chamber, but the air chamber must be large to be of any value. The same thing is true of the suction line, although an air chamber is not so frequently used at this point. One manufacturer provides a small air inlet valve on the suction of the pump which if properly adjusted seems to make the pump operate more smoothly, but of course somewhat reduces its capacity and efficiency.

Valve slam is sometimes due to the fact that the direction of flow through the valve reverses and acquires considerable ve-

locity before the valve closes. This velocity may then carry the valve to its seat rapidly enough to cause a heavy blow when the motion of the valve and the liquid is suddenly stopped. This reverse flow of water through the valve is of course slippage and reduces the efficiency of the pump as well as causing valve slam. The valve should, for these reasons, be heavy enough and so arranged as to close as quickly as possible, and yet not interfere with the operation of the pumper by reducing the area of the ports.

The knocks due to the reversal of stresses in the different parts of a pump are the same as those which occur in any reciprocating machine. If there is any lost motion in a main bearing, eccentric, wrist pin or other part there will be a knock each time the stresses are reversed. The remedy is obvious. All bearings must be properly adjusted and kept properly lubricated.

Centrifugal Pumps

Centrifugal pumps, if they are to handle sludge successfully, must pass solids without frequent clogging. This makes it necessary to use end suction pumps at least 4 inches in size with as few bends and sharp corners in the liquid passages as possible. The impellers usually have only two blades with long sweeping curves and are either fully enclosed or have a shroud on one side. Open impellers clog very rapidly when the liquid contains rags. Even with these precautions, it is generally desirable to have hand holes or other means of access to the interoir.

One pump manufacturing company equips its centrifugal sludge pumps with a screw to force the sludge into the pump and to macerate the solids as they enter. Pumps of this type have been in operation at a number of plants for several years. Similar devices are being made by some other manufacturers but have not as yet come into extensive use.

Capacity and Regulation

A 4-inch centrifugal pump will readily discharge 100 gallons a minute and in some cases as low as 50 gallons a minute, but if capacities below this are necessary some difficulty is apt to be experienced unless provision is made for reducing the speed below that which can be obtained by a direct connected motor. Variations in head, of course, cause variations in the capacity of a centrifugal pump and if a definite quantity of discharge is required some method must be provided to compensate for these variations. In many plants it is necessary to change the quantity of sludge delivered from time to time and provision must be made for so doing. Theoretically, throttling might accomplish these ends, but throttling is not desirable when pumping sludge. If careful adjustment of the quantity of sludge delivered is necessary the only practical method of regulations seem to be to change the speed of the pump. Variable and multi-speed motors will do this within limits but are not as satisfactory as some of the variable speed transmissions available. These transmissions, while expensive, make it possible to obtain almost any capacity within the limits of the pumps. It must not be forgotten, however, that a centrifugal pump will give its highest efficiency at one definite speed and capacity and that as the speed and capacity are changed the efficiency may fall off rapidly. This is naturally of more importance when the pumps are in continuous operation than when they are operated intermittently.

Priming and Seals

Centrifugal pumps will not handle air and when they are used careful consideration must always be given to priming and to the elimination of air pockets in the suction line. To facilitate priming, centrifugal pumps should if possible be set below the surface of the liquid in the suction well. If the pump must be set above the level of the liquid some means of priming must be provided. Foot valves which are often used with water pumps will not serve satisfactorily with pumps handling sludge. Vacuum systems are available and operate satisfactorily if kept in condition, but mean added expense of installation and more equipment for the operator to maintain.

The impeller shaft of every pump of this kind must pass through the pump casing and therefore requires a stuffing box to prevent leakage. On water pumps these stuffing boxes are provided with water seals and the water taken from the pumps. The material handled by a sludge pump is not, however, suitable for the seals and water must be obtained from some source. A direct connection to the water system cannot be used due to the danger of polluting the water supply with sludge. If the building is high enough a small tank fed over the top and controlled by a float valve may be used as a source of water. The height of the tank must be greater than the discharge head of pump or the sludge will be forced into the packing and probably result in the scoring of the shaft. If the tank cannot be set high enough, a small pump may be used to supply water to the seal. Grease seals and other special devices are sometimes used but are not as satisfactory as water seals.

PACKING POINTERS

The following suggestions and warnings, based on the many years of practical experience of a prominent eastern packing manufacturer, will be found valuable in the installation of packings. To follow them may mean freedom from trouble that would occur when even the best packing is improperly installed.

1. NEVER fail to make clear to the manufacturer what the packing is to pack. In other words, with what will the packing make contact?
2. NEVER guess at a size, diameter, width, or height, when ordering packing. Many failures result from small errors in dimensions.
3. NEVER allow too little or too much clearance between follower plate and inside cup wall, or any metal parts behind any upright leather wall. Clearances of 1/16" to 3/32" on each side, depending on size of packing, is recommended.
4. NEVER doctor packing lips with a pocket knife or file, or batter lip in installing. A rounded lip destroys the seal. Packings can be softened by soaking in warm water if necessary.
5. NEVER apply cup packings with flange too high for clearance at the head of the cylinder. Keep systems clean, so sediment will not collect in cylinders and wear the packing.
6. NEVER apply cup packings to end of badly worn plungers; pressure will force the packing down into clearance between plunger and cylinder. Leather washers cut from old cup packings can be made to reline such equipment to proper dimensions.
7. NEVER apply "U" packings where plungers are worn without reinforcing under the heel with leather cushion rings.
8. NEVER look for long service on scored plungers or in scored cylinders; resurface or reline such equipment to proper dimensions.
9. NEVER allow water to corrode cylinder walls, plungers, stems or rods. Use an anti-rust agent that will prevent this and will act as a lubricant.
10. NEVER squeeze hemp or fabric filled "U" packings in glands where such packings are to replace solid section compression packings; set gland up to point where "U" packings are free to function properly.

The above suggestions were contributed by W. F. Schaphorst, M.E., Newark, N. J.

RALPH B. CARTER COMPANY

Hackensack, New Jersey

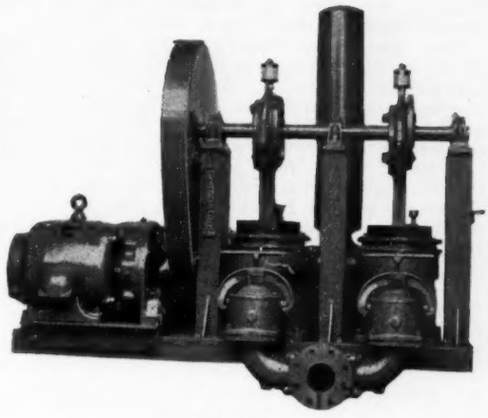
EQUIPMENT FOR SEWAGE TREATMENT AND WATER PURIFICATION

CARTER SLUDGE PUMPS

The installation of Carter Sludge Pumps in a large majority of today's modern sewage plants is proof of established merit. Exclusive features include: Flanged connections throughout the pump; renewable valve seats; successful elimination of all pump pound by an adjustable automatically maintained air cushion in the pump cylinder; babbitt lined eccentrics; properly balanced fly-wheel on the main shaft; chain drive and herringbone reducing gears.

Capacity control by adjustable eccentric drive, by variable speed transmission enclosed with the motor housing, or by variable speed, slip-ring motor.

Capacities from 31.8 to 382.2 GPM, heads from 50 to 115 ft.



Sludge Pump

ALTERNATING SYPHONS

For filter beds in a complete range of sizes from 6″ to 14″. Fully automatic in operation.

CARTER IMPROVED FLOCER—WITHOUT PADDLE AGITATION

10% to 25% shorter detention period.

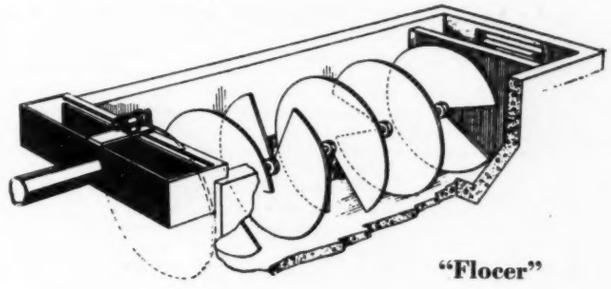
Negligible power consumption.

Low cost installation and maintenance.

A series of flat discs, each with a segment removed, slowly rotated.

Agitation is set up by flow of liquid through the open segments.

Settling occurs between discs during the travel of the open segment in the upper half of rotation. Flocs are not cut up with a final result of a floc of sufficient size to settle rapidly by the time the mixture passes into the settling tank.



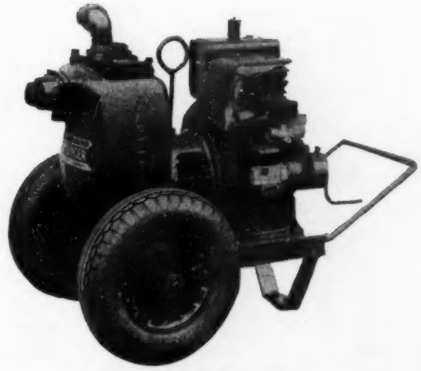
"Flocer"

PADDLE TYPE FLOCERS AND AERATORS

Certain conditions require increased air diffusion in activated sludge treatment. The Ralph B. Carter Company manufactures a full line of paddle mechanisms. Careful design of shaft and bearings assure long trouble-free life under the necessarily difficult underwater operating conditions.

"HUMDINGER" PORTABLE SELF-PRIMING CENTRIFUGAL PUMPS

The only patented priming control guaranteeing 28′ suction lifts. A complete line of dewatering pumps including 2″, 3″, 4″, 6″ and 8″ units. Invaluable for general plant usage. Successfully used for pumping out Imhoff and other type settling tanks, breaking scum, or washing down tank sides.



Portable Pump

SLUDGE CONDITIONERS AND MIXERS

Consult Carter engineers to assure the effective mixing required for proper digestion of sludge. Standard and Pump type rapid mixers also are built for chemical treatment.

COMPUTING HORSEPOWER FROM REVOLVING WATT-HOUR METERS

A simple method of accurately measuring power consumption is of general interest to the owner or operator of any electrically driven pump. A periodical record of the power consumption, capacity of the pump, and the measurement of the pumping level assists in maintaining operation at maximum efficiency and gives an indication as to the proper time for reconditioning or modernizing the installation.

The power consumption is measured by the Watt-Hour Meter, usually located on the switchboard in the pump house adjacent to the motor. Large units require current and/or potential transformers, so that the watt-hour meter reading must be multiplied by the ratio of these transformers to obtain the correct measurement of power consumption of the motor.

A motor which draws 200 amp. at 440 volts may be metered through current transformers rate 200 amp. primary and 5 amp. secondary, so that 5 amp. would pass through the watt-hour meter. No potential transformers being used, the watt-hour meter reading, multiplied by the ratio of 200 to 5, would give the amount of power in the main circuit.

Asssuming that a motor draws 600 amp. at 2300 volts, potential as well as current transformers are required. If the ratio is 60 to 5 amp. on the current, and 2300 to 115 on the potential transformers, the watt-hour meter reading multiplied by the ratio of 60 to 5 and in addition, by the ratio of 2300 to 115, will give a true measure of the power consumption in the main circuit. The correct ratio is usually stamped on a brass nameplate attached to the transformer.

Disk constants and multipliers for practically all modern watt-hour meters now in use for single and three phase, 110-220-440 volts are shown in the chart below.

Use of Chart

First determine the make, type, volts and amp. of the meter. If no current or potential transformers are used, refer to the chart and determine M value for the meter. The M × r.p.m. of disk = hp. input to motor for example, a meter, G.E., type D-3, 220 volt, 15 amp., K = 4.0, M = .3217, number of revolutions of disk in one minute = 20. Then .3217 × 20 = 6.434 h.p. input to motor.

As another example consider an installation where current transformers having a ratio of 20 to 1 are used. Meter, Westinghouse type OA, 220 volt, 5 amp., K = 1⅓, M = .1027, number of revolutions of disk in one minute = 21. Then, .1072 × 21 × 20 = 45.02 h.p. input to motor.

Disk constants K are included in the accompanying chart because occasionally the manufacturer's nameplate has been removed, in which event the constant K is marked on the meter. To determine the M value in such cases, find a K in the table corresponding to that on the meter in question. The M applying will be the one adjacent to and on the right of this K.

Definitions:

K—A constant which represents the number of watt-hours passed through the meter while the disk makes one revolution.

M—A factor which, when multiplied by the number of revolutions of the disk, in one minute, gives h.p. input to motor.

Mathematically, $M = \frac{K \times 60}{746}$

The h.p. values expressed above relate to input to motor. The rating of motors is in terms of h.p. output. Therefore, the h.p. output or brake h.p. is determined by multiplying the h.p. input by the motor efficiency, which can be obtained from the motor manufacturer.

Chart of Constants and Multipliers

For Use in Determining KW Input, HP Input or BHP from Revolutions of Watthour Meter Disks

110 Volt—Single Phase

Amp.	General Electric 1		General Electric 1-10		General Electric 1-14		General Electric 1-16		Sangamo H		Westinghouse B, C, OA, OB	
	K	M	K	M	K	M	K	M	K	M	K	M
5	.3	.0241	.25	.0201	.3	.0241	.6	.0483	5/24	.0168	⅓	.0268
10	.6	.0483	.5	.0402	.6	.0483	1.2	.0965	5/12	.0335	⅔	.0536
15	1.0	.0804	.75	.0603	.9	.0724	1.8	.1448	5/8	.0503	1	.0804
25	1.5	.1206	1.25	.1005	1.5	.1206	3.0	.2413	2 5/24	.0838	1⅔	.1340
50	3.0	.2413	2.5	.2011	3.0	.2413	6.0	.4826	2 1/12	.1676	3⅓	.2681

220 Volt—Single Phase

Amp.	General Electric 1		General Electric 1-10		General Electric 1-14		General Electric 1-16		Sangamo H		Westinghouse B, C, OA, OB	
	K	M	K	M	K	M	K	M	K	M	K	M
5	.6	.0483	.5	.0402	.6	.0483	1.2	.0965	5/12	.0335	⅔	.0536
10	1.25	.1005	1.0	.0804	1.2	.0965	2.4	.1930	5/6	.0670	1⅓	.1072
15	2.0	.1609	1.5	.1206	1.8	.1448	3.6	.2895	1 1/4	.1005	2	.1609
25	3.0	.2413	2.5	.2011	3.0	.2413	6.0	.4826	2 1/12	.1676	3⅓	.2681
50	6.0	.4826	5.0	.4021	6.0	.4826	12.0	.9651	4 1/6	.3351	6⅔	.5362

110 Volt—Three Phase

Amp.	General Electric D-3		General Electric D-6 & D-7		General Electric D-14		Sangamo H		Westinghouse C, OA, OB, RO.	
	K	M	K	M	K	M	K	M	K	M
5	.6	.0483	.6	.0483	1.2	.0965	5/12	.0335	2/3	.0536
10	1.25	.1005	1.2	.0965	2.4	.1930	5/6	.0670	1 1/3	.1072
15	2.0	.1609	1.8	.1448	3.6	.2895	1 1/4	.1005	2	.1609
25	3.0	.2413	3.0	.2413	6.0	.4826	2 1/12	.1676	3 1/3	.2681
50	6.0	.4826	6.0	.4826	12.0	.9651	4 1/6	.3351	6 2/3	.5362

(*Continued on next page*)

220 Volt—Three Phase

Amp.	General Electric D-3		General Electric D-6 & D-7		General Electric D-14		Sangamo H		Westinghouse C, OA, OB, RO.	
	K	M	K	M	K	M	K	M	K	M
5	1.25	.1005	1.2	.0965	2.4	.1930	5/6	.0670	1 1/3	.1072
10	2.5	.2011	2.4	.1930	4.8	.3861	1 2/3	.1340	2 2/3	.2145
15	4.0	.3217	3.6	.2895	7.2	.5791	2 1/2	.2011	4	.3217
25	6.0	.4826	6.0	.4826	12.0	.9651	4 1/6	.3351	6 2/3	.5362
50	12.5	1.005	12.0	.9651	24.0	1.930	8 1/3	.6702	13 1/3	1.072

440 Volt—Three Phase

Amp.	General Electric D-3		General Electric D-6 & D-7		General Electric D-14		Sangamo H		Westinghouse C, OA, OB, RO.	
	K	M	K	M	K	M	K	M	K	M
5	2.5	.2011	2.4	.1930	4.8	.3861	1 2/3	.1340	2 2/3	.2145
10	5.0	.4021	4.8	.3861	9.6	.7721	3 1/3	.2681	5 1/3	.4289
15	7.5	.6032	7.2	.5791	14.4	1.158	5	.4021	8	.6434
25	12.5	1.005	12.0	.9651	24.0	1.930	8 1/3	.6702	13 1/3	1.072
50	25.0	2.011	24.0	1.930	48.0	3.861	16 2/3	1.340	26 2/3	2.145

hp. Input = "M" × Revolutions per minute of Disk

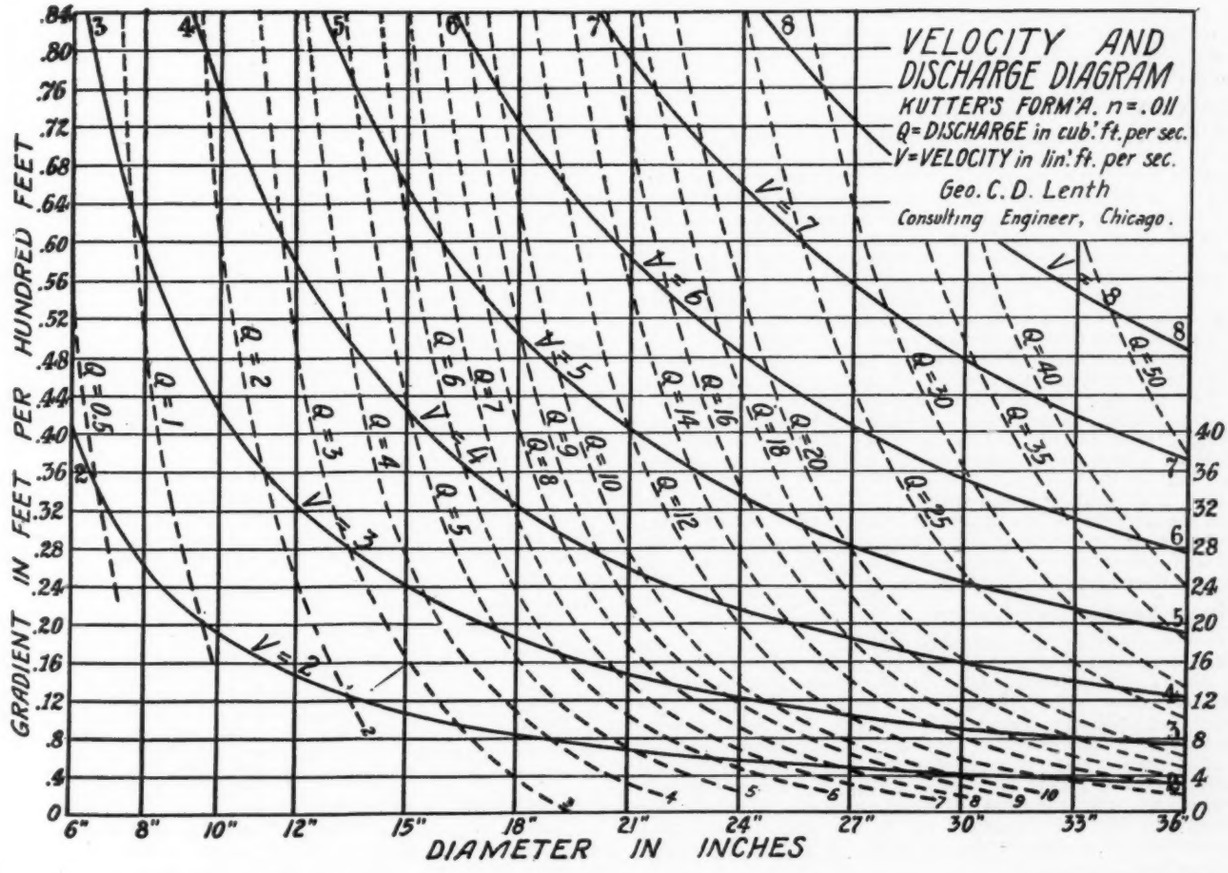
hp. Input = $\frac{\text{"K" × Number of Revolutions × 3600.}}{\text{Sec. × 746}}$

Important—Where instrument transformers are used, be sure that figure computed from revolutions of disk and table be multiplied by ratio of instrument transformers.

(From Byron-Jackson Bulletin, "Deep-Well Turbine Pumps.")

Velocity and Discharge Diagram for Vitrified Clay Sewer Pipe

(Courtesy, Clay Products Assn.)


VELOCITY AND DISCHARGE DIAGRAM
KUTTER'S FORM'A. n=.011
Q=DISCHARGE in cub. ft. per sec.
V=VELOCITY in lin. ft. per sec.
Geo. C. D. Lenth
Consulting Engineer, Chicago.
GRADIENT IN FEET PER HUNDRED FEET
DIAMETER IN INCHES
6" 8" 10" 12" 15" 18" 21" 24" 27" 30" 33" 36"

(Example: Assume 12 cu. ft. per sec. as the flow to be handled. The gradient for instance, to be a 0.2 ft. per 100 ft. run. Follow to right from gradient figure 0.20 on left until Q12 dotted line is intersected. The vertical line found at that point indicates that a 24 inch sewer is required. Also from the nearest velocity curve V.4 at the intersection it is revealed that the velocity will be 3.8 ft. at full or half full flow.)

METERING MODERN SEWAGE WORKS

By ROBERT T. REGESTER

Consulting Engineer, Baltimore, Md.

Flow measurement furnishes an essential part of a treatment process.

In general, the extent to which Venturi metering equipment is provided in sewage works increases with both the capacity of the plant and the completeness, or degree, of treatment to be accomplished.

In many large American cities, where sewage works have been constructed and enlarged within the past ten years, local conditions have warranted the highest degree of treatment. Accordingly, works of the activated sludge type were built.

"Complete" Metering

There is a decided trend toward "complete" metering—especially for works of the activated sludge type. This type of works, providing complete treatment together with the pumping of raw sewage, offers the most numerous applications for metering equipment. The trend is justified from the standpoints of both proper process functioning and operating economy. This tendency is reflected in several more recent designs where provision is made for the parallel operation of similar tanks under different flow conditions. The best combination of variable relationships thereby can be determined. Of course, operation in this manner is intended to be periodic, as the occasion demands, rather than regular. By such means, unfavorable influences can be observed and closer control effected. The works can serve the role of a full-scale pilot plant. In very large works, batteries of similar tanks can take the place of individual tanks so arranged.

Activated sludge works are extensively mechanized and electrified. They present a somewhat complicated arrangement because of the multiplicity of treatment units and process steps. The diagrammatic arrangement here shown serves to illustrate the application of metering equipment for both measurement and regulation of flows to the principal units. This typical layout assumes groups of four units arranged for maximum flexibility and control.

Measurement of Raw Sewage

It is often necessary for raw sewage to be pumped from the outfall sewer to such elevation as will produce gravity flow through the entire plant. Individual centrifugal pumps are metered so that periodical checks can be made on the efficiencies of the respective units. These meters may be equipped with only portable manometers, calibrated directly in rate-of-flow units. On the other hand, individual indicating-recording instruments would show at a glance the immediate performance and would also provide a record of past performance for each pump. This latter scheme is not uncommon in pumping station design.

It is most desirable to provide means for readily ascertaining the total sewage flow to the works. This can be accomplished either by summation (electrically and continuously) of the rates of flow through the individual pump meters, or by providing a separate master sewage meter. In the case of divided flow after pumping, to suit an immediate or future duplicate arrangement of plant, a separate master meter should be provided to serve each half of the layout.

In a large plant it is convenient to have an indication of the total sewage rate of flow at several strategic locations other than at the sewage pumping station. Electrically-operated transmitters and indicators are now used to repeat the summation or master meter readings to such remote points.

Primary Settling Tank Control

It is desirable to have individual settling tanks perform equal duty. As a means of equalizing flows to the units of a battery of these tanks, individual meters with regulating valves can be advantageously used. The valve can be of one of several types, either hydraulically or electrically operated, inserted in the recovery tube of the meter for each tank. This permits the use of a smaller size valve. To minimize the effect upon meter accuracy, the valve should be placed at least two throat-diameters downstream from the throat pressure chamber. The indicating instruments and valve controls can be arranged, for operating convenience, on a control table or panel.

Aeration Tank Control

In the aeration tanks, a properly-proportioned mixture of settled sewage and return sludge from the final settling tanks is agitated and maintained in an aerobic condition by the introduction of compressed air.

The settled sewage, return sludge and air can be metered independently just prior to entering each aeration tank. The sewage and return sludge then mixes upon entering the tank. The air is distributed lengthwise of the tank through porous diffusers arranged along one wall so as to produce a spiral flow of the mixture. When all three meters are arranged at the inlet end of each tank, they can be grouped within the gallery which is usually provided, for the various pipes and feeding channels, along the full width of a battery of aeration tanks.

With an arrangement of independent meters, each meter can be equipped with a regulating valve, as previously described, to permit individual control. For the return sludge, a Venturi rate-of-flow controller may be used, instead of a meter with regulating valve, for each tank. In either case, an automatic control to maintain a predetermined rate can be provided.

A five-dial ratio gauge for the three meters of an aeration tank has been developed. This gauge will indicate, or indicate and record, the rates of flow of air, sewage and return sludge using the first, third and fifth dials, respectively. The second dial will give the ratio of air to sewage, calibrated in cubic feet per gallon. The fourth dial will give the ratio of return sludge to sewage, calibrated in percentage of the sewage flow. The gauges are mounted on control tables which also contain the controls for the respective regulating valves.

Final Settling Tank Control

Final settling tanks remove the floc from the mixture which leaves the aeration tanks. The clarified supernatant liquor passes off as the final treated effluent, to be discharged into the receiving body of water. Meters with regulating valves may be used to equalize the flow of these tanks in the same manner as described for the primary settling tanks. This may only be desirable in the case of numerous units where perhaps one unit is likely to be out of service frequently. Otherwise, the effluent from each aeration tank can flow directly to a corresponding final tank by suitably arranging either stop planks or sluice gates. If these meters are included, they can be grouped with the aeration tank meters in the same gallery, provided that the aeration tanks are of a two- or four-pass type.

For the withdrawal of activated sludge from each final tank, an automatically controlled regulating valve with meter, or a rate controller, is very desirable. There are several other devices, such as adjustable overflow pipes and air lifts, which are also used for controlling the rate of sludge withdrawal. Here again, indicating and recording instruments, controls and push button stations for various motor-driven equipment can be grouped on suitable control tables or panels.

Measurement of Air

In the blower house, each centrifugal blower is provided with a Venturi meter on the intake to measure the flow of free air. These meters are essential for the efficient operation of the blowers and should be provided with individual indicating-recording instruments.

As in the case of the total sewage flow, it is also desirable to provide means for readily ascertaining the total compressed air flow from the blower house, and for repeating this reading in terms of free air to other locations. The previous remarks relating to the master sewage meter apply equally well to a master air meter.

Measurement of Sludge

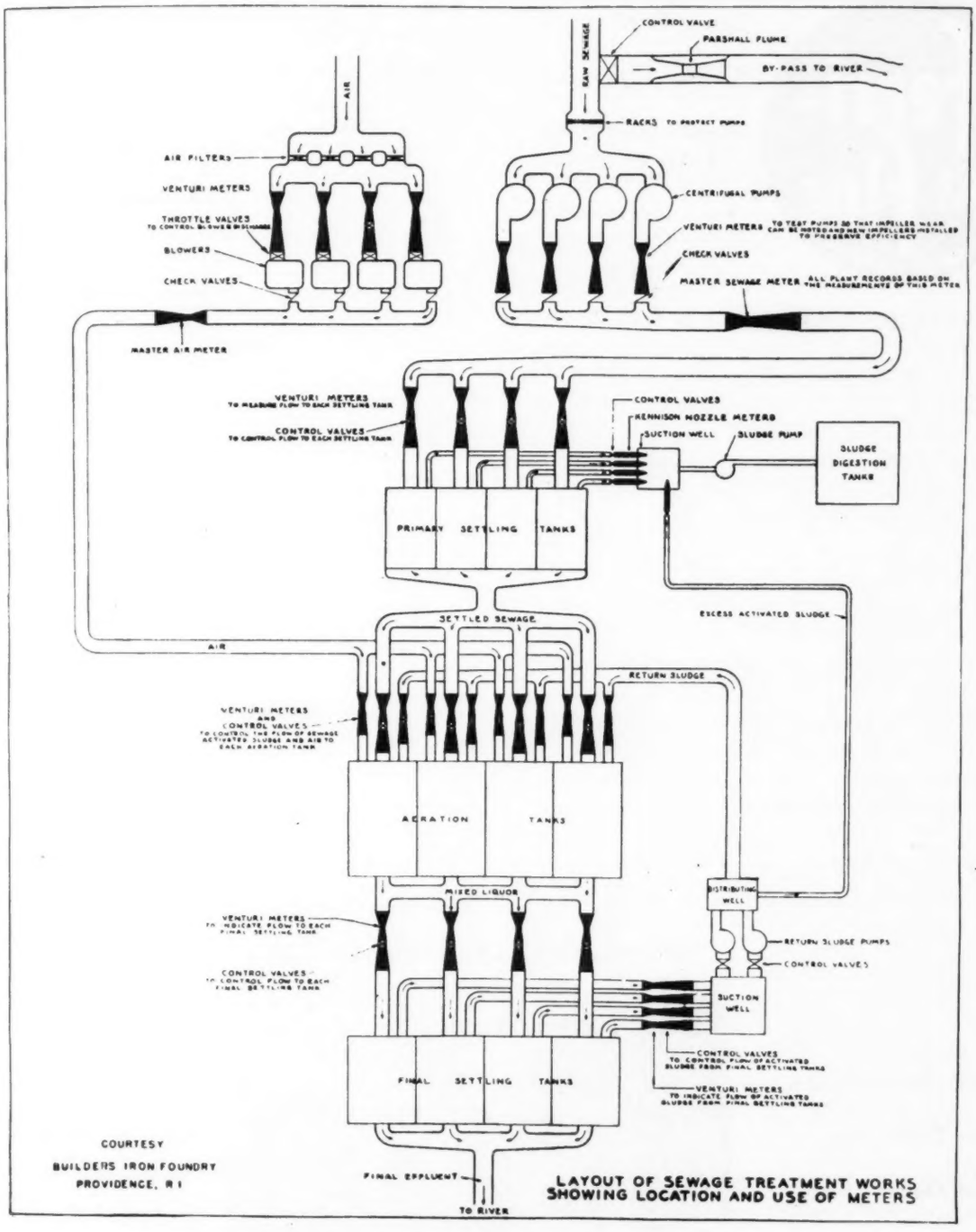
The measurement of sludge has been a problem in sewage works because of the nature of the material and the relatively small flows encountered. The Kennison nozzle meter is now being used for this service. The nozzle is of special free-blowing design, utilizing the depth produced by a shaped outlet as the rate-of-flow function. The nozzle is equipped with an indicating-recording instrument. These nozzles can be used for measuring the raw sludge and the excess activated sludge prior to digestion.

In Conclusion

The cost of providing "complete" metering does not become a major item in the overall cost of sewage works designed for complete treatment. This cost, excluding regulating valves and special control devices, will approximate 3 to 5 per cent of the total cost.

In addition to the applications of Venturi metering equipment already discussed, there are many other special uses for related devices in modern sewage works, especially for control and regu-

lating purposes. These include automatic pump controllers, sampling devices, by-pass regulators, constant liquid level controllers and the like. Many such applications comprise combinations of proven mechanical and electric elements backed by the experience and integrity of reputable manufacturers. However, it is the designing engineer's province to originate and supply these combinations for specific problems. Following in the path of industrial advances in the art of automatic control, sanitary works, too, are being so equipped. Most of the features described herein were embodied in the designs for the Columbus and Baltimore activated sludge works, with both of which the writer has been or is now associated.



Layout of an Activated Sludge Plant Showing Location and Functions of Meters.

TENNESSEE CORPORATION

Atlanta, Georgia — Lockland, Ohio

WATER AND SEWAGE TREATMENT — SLUDGE CONDITIONING

Ferri-Floc — FERRIC SULPHATE

Lower Cost

Simpler Operation

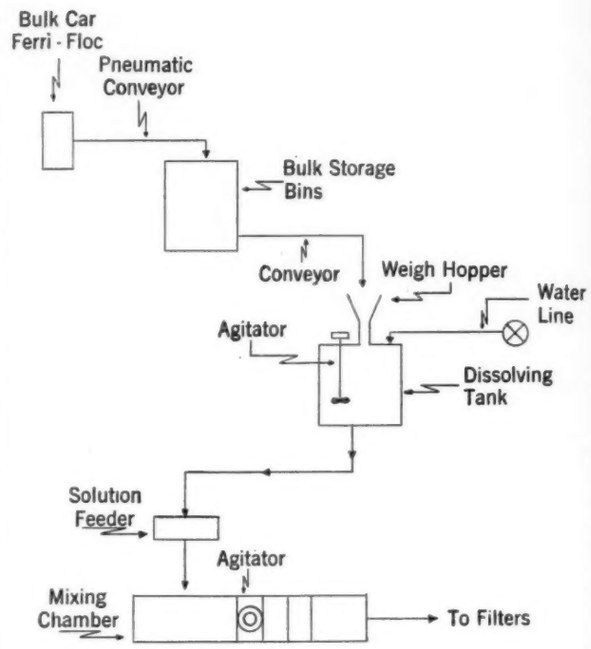
Higher Plant Food Value of Sludge

Handle only one chemical in Dry Form in Bulk or Bags

FERRI-FLOC (Tennessee Ferric Sulphate) is the coagulant for all types of water and sewage treatment. Ferri-floc is widely used:—to condition sludge for vacuum filtration or drying bed disposal; for treatment of industrial wastes from textile mills, paper mills, etc., for removal of dissolved chemicals and organic matter; for treatment of drinking water supplies where a Ferric Salt is indicated for best coagulation.

Advantages:

1. Complete stability permits satisfactory storage over long periods, unaffected by moisture.
2. Can be fed through dry feeders as well as solution feeders.
3. Eliminates the worry of maintaining proper Chlorine-Iron ratio to prevent residual iron.
4. Eliminates need of costly equipment for preparation of Ferric Salts—ferri-floc is oxidized and ready to use.
5. Filter cloths last longer.
6. Low operating, feeding and storage costs.



Diagrammatic Sketch Showing
FERRI - FLOC
Handling and Feeding
in Sewage Treatment Plants

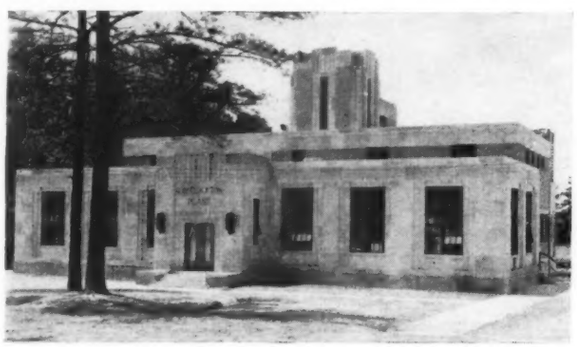
PARTIAL LIST OF INSTALLATIONS

City of Houston, Tex.

City of Dallas, Tex.

City of Dalton, Ga.

City of Atlanta, Ga.



Chemical and Power Building
R. M. CLAYTON SEWAGE DISPOSAL PLANT
City of Atlanta, Ga.

City of Greeneville, Tenn.

City of Anderson, Ind.

Swift & Company

Gulf Oil Corp.

and others.

COPPER SULPHATE AS AN AID TO SEWER MAINTENANCE AND SEWAGE TREATMENT

By JOHN W. HOOD, Superintendent
Sewage Treatment Works, Ridgewood, New Jersey

BASED upon our experiences in Ridgewood, N. J., the benefits to be derived from the application of copper sulphate to sewers and house service lines are the following:

1—Odor Control.
2—Reduction in Chlorine Requirements.
3—Better and Less Costly Treatment at the Plant.
4—Root Removal.

Not the least of these is the last item, which, together with the other benefits noted, should interest superintendents of sewerage systems and treatment plants in this powerful and effective copper salt as an aid in sewer maintenance and plant operation.

Odor Control and Reduction of Chlorine Demand

Sulphuretted hydrogen odors, sewerage systems and sewage treatment plants have been so closely associated for so long that they have come to be identified as an inevitable combination. George W. Fuller, in a chapter of his text devoted to desulphurization, writes as follows: "There is no known way of preventing the formation of H_2S, which is released from organic sewage matters by a great variety, and perhaps most kinds of bacteria . . . In the event that it is true that there are but very few species of bacteria capable of producing hydrogen sulphide through the reduction of the mineral sulphates, it may be feasible to find some way of destroying such growths. It would be better yet to find some means of preventing such growths from becoming seeded in works on account of the importance of guarding against the resulting solvent actions that disintegrate masonry and metal structures. It seems to be a fruitful field for the laboratory man to develop."

These excerpts are typical of the numerous texts which were canvassed.

A remarkable aspect of the H_2S problem at the Ridgewood Sewage Treatment Plant was the heightening of odors during the winter months, when sewage influent temperatures ranged between 34° F. and 40° F.

Chlorine demands of sewage entering the plant had been variously determined at bewteen 25 and 35 ppm.

A portable chlorinating station was located on the trunk line upstream from the plant and as much as 150 pounds per day, or 16 ppm., based on the flow, were necessary for the control of H_2S odors alone during these winter months.

Thinking in terms of the biochemical aspects of the problem, microscopical examinations of fungi samples taken from various points in the sewer system were made.

A predominance of *Beggiatoa,* a motile filamentous fission fungus, which morphologically resembles the algae oscillaria, was disclosed by these examinations. The ciliated protozoon, *Paramaecium,* was very numerous and active within the parent structure of *Beggiatoa,* moving briskly in all directions. *Uroglena* was also well represented. These three being the major groups, no further examination was made for other types present.

Five out of six references were of the opinion that *Beggiatoa* existed in symbiosis with one or more species of so-called true sulphur bacteria. The sixth reference, "Bergey's Manual of Determinate Bacteriology" (Williams and Wilkins), stated that *Beggiatoa* was capable of reducing sulphates, secreting the armorphous sulphur within their cells, as had been observed in the microscopical examinations. In view of the preponderance of *Beggiatoa* it was felt that the sixth reference was in this case the correct one and that no state of smybiosis existed.

Having failed to dislodge these extensive growths of sulphur bacteria from the system by the application of chlorine, the use of copper sulphate was next considered. On referring to the Nichols Copper Co. publication on the application and uses of copper sulphate, it was noted that five parts per million of $CuSO_4$ were necessary to destroy *Beggiatoa* and work was immediately begun on its application.

Small doses of the chemical (a grade of medium crystal size being employed) were placed in terminal manholes and intermediate intersection manholes, where inspection disclosed that the fungus was growing profusely.

Two barrels of $CuSO_4$ was thus distributed in the system over a period of several days, and upon completion of this work the flushing of sewers was commenced. It was reported that in some lines the pipes were literally filled with the dislodged fungus. As a result of this preliminary treatment and several subsequent treatments of the sewerage system with $CuSO_4$ odors were eliminated to such an extent that up-sewer chlorination was discontinued and pre-chlorination at the plant proper was necessary only during the warmer summer months.

A saving of more than $1,000 per annum for chlorine for odor control at Ridgewood has resulted from the copper sulphate treatment on the sewerage system.

Root Removal

Cleaner Sewers and Better and Cheaper Treatment

Chemical coagulation difficulties at the Ridgewood Treatment Works were found to be due to a high pH-alkalinity equilibrium, and this condition was in turn found to be caused by septization and attendant mineralization of the sewage in the sewerage system. Close watch on sewer troubles disclosed that they were mostly due to roots entirely clogging the house connections. Visualizing each pipe as being wholly or partially clogged by fibrous root tendons, it was obvious that sewage solids would be retained on the up-stream side of the "mat" to decompose, while the filtrate seeped through in course of time. This condition afforded an ample structure within which the ready evolution of anaerobic life and activity, attended by favorable conditions of little or no air, warmth, and fresh organic matter daily could proceed.

A Study of Treatment of House Connections

Several connections whose outlets were available for sampling were selected from a sewer map. They were located in sandy terrain and it was not unexpected that the owners, when approached for permission to experiment, readily granted the desired permission and told of repeated sewer trouble and plumber bills.

The property owner was informed of our intention to use copper sulphate and it was specially emphasized that $CuSO_4$ had no magic qualities; that it merely had a toxic property capable of killing live roots which would in time break loose or disintegrate and be swept out by the flow of sewage. It was also emphasized that these root growths within the pipe were 10-15-20 year standing; that we had no way in which to ascertain the extent of their infiltration and the amount of copper sulphate which would be necessary to kill them all.

Success crowned these efforts and a comparison of analysis made before and after the copper treatment showed that in all cases the pH-Alkalinity equilibrium had declined. When subsequent determinations disclosed a calcium carbonate equilibrium more nearly resembling the city water, the connection was considered clear and no further treatment given.

Results Noted

A short street of seventeen homes having a bad record of sewer stoppage due to roots was next tackled. After several weeks the determination showed a decline in equilibrium from pH 7.9 and alkalinity of 435 ppm. to pH 7.7 and alkalinity of 227 parts. It is important to state that before the copper treatment of house connections in this street, the sewage was not responsive to any dose of chemical coagulant, whereas afterwards it was found to be amenable to chemical clarifications with much smaller doses than had been previously tried.

When a year had elapsed from the completion of work on this street, each connection was gone over with sewer cleaning equipment. All connections were found clean and clear, no roots being brought out by the equipment.

As a result of these applications of copper sulphate crystals to the sewers in the streets, and a relatively small percentage of the house connections, the influent to the plant has been brought within such limits of the calcium carbonate equilibrium the year around as to be amenable to chemical precipitation at a materially lowered cost.

Some years ago Merle F. Koblish of the General Chemical Co. applied the calcium carbonate equilibrium yardstick to his coagulation problems in Long Island and reported as follows:

1. pH 7.0 and Alkalinity of 100-125. (Very easy and cheap to coagulate.)
2. pH 7.5 and Alkalinity of 125-175. (Increasing difficulty.)
3. pH 7.5 to 8.0 and Alkalinity of 200 ppm. or over. (Difficult to treat.)

This has been the writer's experience also and if copper sulphate can be employed to modify the equilibrium it is obvious that treatment difficulties will diminish. However, this is only

true of high equilibrium due to the bio-chemical processes going forward in the root masses. Where industrial wastes are the cause, it would seem that dilution would effect the necessary modification.

Some Practical Pointers Concerning Application of Copper Sulphate

I have been requested by the Editor of WATER WORKS AND SEWERAGE to state definite amounts and procedure for the benefit of readers who wish to tackle their root troubles with copper-sulphate.

Since the extent of the root growth in any given pipe is unknown, a greater or lesser amount of the crystals may be required to permeate the whole mass.

An individual root mass entering at one point may clog a pipe or connection just as effectively as half a dozen, but obviously more crystals would be necessary for the greater quantity of roots.

Property owners and occupants furnish "case histories" by relating their woes with their sanitary connection, and the extent of the root growth may be deduced from their statements.

House Connections

As previously stated, crystals are applied through the commode within the home. The operator carries a cotton bag containing the crystals and puts 2 or 3 pounds through each connection. Where serious trouble and recurrent plumber visits have been experienced by the tenant, initial doses of 6 to 10 pounds have been applied in an attempt to insure complete contact and such cases have been marked down for repeat doses at weekly, fortnightly or monthly intervals, as the conditions seem to dictate. After the initial high dose, and in the absence of any further clogging troubles, normal low doses of crystals may be used.

When a connection is completely plugged and overflowing, rodding must be resorted to to restore flow through the root masses. Thereafter copper sulphate crystals may be applied, but not before. There has to be some flow through the connection in order to carry the solution down through the roots for the attack.

Street Sewer Mains

A light truck and a barrel of copper sulphate crystals are the operator's tools. Junction and terminal manholes are opened, a small scoopful of crystals are sprinkled along the invert of the pipe, and the manhole cover replaced. Thereafter the flow gradually dissolves the crystals and the resulting solution contacts roots and fungi as it flows down-stream. About 2 pounds per manhole is applied, but here again this amount is increased as in the case of the house connections, when records indicate serious root trouble.

Under no circumstances should an amount of crystals sufficient to obstruct the flow be placed in the inverts, nor should crystals be placed in the traps of automatic siphon type flush tanks. In the first place, they will not dissolve due to the absence of flowing water, and secondly, they may tend to corrode the metal.

It is recommended that periods of normal to low flow be chosen to introduce the copper sulphate. Both the time of contact and the concentration of the solution are thereby enhanced. A preventative dosage may be given annually following the initial treatment. Old roots do not return, but new root infiltration may develop.

Records

Careful records of all work should be kept so that not only will the results be disclosed, but eventually all of the system and house connections may be serviced.

Some Important Don'ts

Don't put $CuSO_4$ crystals in fixture traps. Corrosion by interchange of metallic ions will occur and eventually eat holes in the traps. Flush the crystals through the commodes when applying from within homes, and follow with a sufficient amount of flushing water to insure (1) their transit through the soil pipe to beyond the cellar wall and (2) their conveyance to and against the root obstruction, where the crystals will dissolve discharging the solution slowly into the root mass.

Don't expect black magic properties from $CuSO_4$. Remember that a good root mass is well-nigh impervious to concentrated sulphuric acid. Only the life is taken by copper sulphate treatment and thereafter the normal processes of decay must ensue.

Don't waste $CuSO_4$ in the system during periods of high flow. The dilution factor is too great and the resulting concentration of the solution too weak to be effective. Pick low-flow periods.

Don't expect $CuSO_4$ to clean sewers and house connections mechanically obstructed by breakage, bad connections or faked bends. The amount used on a system in any given time should be arrived at by collaboration with the plant superintendent, who is best able to determine what traffic will stand, by close observation of the biological and/or chemical processes incorporated in the plant.

KILLING ROOTS IN SEWERS WITH COPPER SULPHATE

By J. W. McAMIS

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Roots give a great deal of trouble in the smaller sewers, by causing stoppages wherever they may happen to find an entrance into the pipes carrying domestic sewage.

For four or five years now we have been using copper sulphate to combat this trouble.

We have a man whose duty it is to visit each manhole in the system at least once each month, looking for stoppages. He carries along on these trips a small bag or bucket of copper sulphate and drops a small handful of crystals down into the flowing sewage wherever he finds that the stoppage is downstream.

After a reasonable amount of experience in this work a man can tell pretty well where trouble is to be expected in the near future, by the nature of the flow of the sewage and by the conditions in the bottom of the manhole.

In cases where stoppage is due to roots, sewage will back up into the next manhole above during periods of greatest flow during the day and will recede during periods of low flows. This condition may exist for days or possibly weeks before the sewage begins to overflow the top of the manhole and run into the street. By throwing in the copper sulphate crystals *while the sewage is still flowing,* a sufficient concentration of the poison will usually reach the seat of the trouble to eliminate it before the stoppage is complete.

At Greenville, we have the same man doing this work that looks after the disposal plants and he tells me that he can predict almost exactly when the balls of roots will turn loose and come down to the treatment plant following the copper treatment.

Since we have been using this scheme it is a rare day when we have to send out a truck with sewer-rods and other equipment to open up a stopped sewer.

Regarding the exact quantity of the sulphate required for good results, I have attempted no determination of the necessary concentration of copper sulphate. However, it is my opinion that the length of the contact period is a more important factor than the actual concentration of the copper sulphate. To illustrate; the ideal condition seems to be where a small flow of sewage, say two to five g.p.m., is just trickling through a mass of roots. In a case like this a small handful of the chemical applied in the manhole just upstream from the stoppage will do the trick.

If the flow is greater, as determined from looking in the manhole just below the stoppage, greater quantities and possibly repeated applications would be necessary. If it is kept in mind that it is time of contact that is important, rather than the amount of copper sulphate, no trouble should be experienced in carrying out this operation.

Another important point to remember is that it is useless to apply the copper sulphate in a sewer that is completely stopped, for unless there is at least a small flow of sewage through the obstruction there is no chance for contact between the roots and the copper solution. Sewer rods would be the only remedy here—at least to start some flow through and allow the copper to reach the roots. (Since it is only necessary to kill the small root which enters the sewer, and not the great mass of roots branching from it, the important factor is that of reaching the feeder root with the killing chemical. Then, the flow pulling on the large heavy "brush," causes the weakened base root to break. Prechlorination of sewage has been found to produce the same results on root infected sewers but is not so simply applied as the copper treatment.—Ed.

SEWAGE TREATMENT PLANT OPERATION

Compiled from Various Sources

By A. P. BANTA

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A DAILY inspection of each major unit of the plant by the plant operator should be made, any unusual conditions recorded, and faulty conditions immediately remedied. The plant operating data should be fully compiled each day, and kept, as an aid in maintaining the plant in proper operating condition. Such records are valuable for future reference and as evidence.

It is especially important that the daily flow or rate of flow of sewage reaching the plant be measured and recorded. Methods commonly employed to determine sewage flow are as follows:

1. Weir measurements.
2. Counters on dosing tanks of known capacity.
3. Capacity of pumps and period of operation.
4. Recording meters (Venturi, weir, etc.).
5. Dosing tank period for filling.

Records of power consumption and supplies, tools or chemicals obtained should be maintained. A daily log book for keeping such records and information concerning general or unusual conditions is very useful.

The air temperature, wind direction and general weather conditions should be recorded daily. This information is valuable in the investigation of nuisance complaints such as odors.

It is also essential that a few simple tests be made to determine the efficiency of separate units of the plant or of the plant as a whole. The results of these tests and a record on operation will:

1. Indicate to the operator whether the plant is or is not functioning properly.
2. Aid the municipality or institution in case of law suits resulting from alleged pollution or nuisance.
3. Assist consulting engineers in planning changes or additions to the plant.
4. Enable the officials responsible for the operation of the sewage disposal plant to prepare reports to the public and to the State Department of Health on the operation and efficiency of the plant.

The operator should have for ready reference plans or blue print designs of the plant, showing the dimensions of each unit and all pipes, valves, gates, etc., in order that he may be able to fully understand the construction and operating details of the plant.

A competent sanitary engineer can materially improve operating conditions through guidance and advice. It would be advisable for municipal or other officials to retain consulting engineers, or an experienced operator from a nearby plant, for a few years after completion of a new plant in order to supervise plant operation. Operating difficulties may frequently be prevented or readily corrected by following their advice.

Operators of sewage treatment plants should always remember that sewage gases are combustible and also explosive under certain conditions. Such gases may be toxic and asphyxiating. It is, therefore, necessary to take unusual precautions where such gas may be present either in the sewer system or at the treatment plant. No open flames or other sources of ignition should be permitted. Adequate ventilation of manholes and other similar enclosures before entering is always advisable. Moreover, no one should ever enter a place where such gases are likely to be present without an emergency rope attached to his person and two watchful attendants stationed outside. When the gases are toxis, i. e., containing poisonous gases, a special gas mask should also be used.

The following are a few fundamental details of the proper operation of sewage treatment plants. Local conditions may alter somewhat the following operating details but in general these notes give a resume of the operating procedure for the various types of treatment described.

Grit Chambers

1. Grit chambers should be cleaned after every large storm.
2. Grit chambers should be cleaned whenever tests show that the grit compartment (the compartment below the inverts of entering and outlet channels) is filled with hard material to 50 or 60 per cent of its capacity.
3. The grit should be promptly disposed of by burying it or drying it on sludge beds. If it is sufficiently clean, it may be used for filling in low land.

Coarse Screens (1/2-Inch to 3-Inch Openings)

Screenings, unless properly disposed of, are frequently a serious source of nuisance at a treatment plant because they decompose readily, giving off obnoxious odors. They will also encourage the breeding of rats and flies unless properly cared for. Furthermore they are unsightly and repulsive to visitors.

1. Remove the screenings twice daily or oftener if necessary to prevent clogging of the screen and consequent backing up of sewage in the outfall sewer.
2. Promptly dispose of screenings by:
   (a) Burial, covering by at least 12 inches of earth, either by ploughing under the soil or shallow trenching. They may be placed in trenches, treated with borax, chloride of lime, or other disinfectant and covered with earth as early as possible.
   (b) Incineration where possible.
   (c) Grinding, either returning ground material to the sewage flow or mixing it with the primary tank sludge going into digesters.
3. Clean the screen chamber, removing all accumulated sludge and grease, at least once a day.

Fine Screens (1/2-Inch or Less)

1. Fine screens are usually continuously mechanically cleaned, either by water, air or revolving brushes, and therefore all moving parts should be properly lubricated to keep them in proper working condition.
2. Remove and dispose of screenings promptly by:
   (a) Mixing with garbage and incinerated.
   (b) Dewatering by pressing, and then incinerating or burying the solids.
   (c) Burial, covering by at least 12 inches of earth, either by ploughing under the soil or shallow trenching. They may be placed in trenches, treated with chloride of lime, or other disinfectant, and covered with earth as early as possible.
   (d) Digested with other solids removed by sedimentation.

Septic Tanks

1. Sludge and scum should be removed whenever they accumulate to a combined depth equal to 1/4 the depth of the tank below the flow line.
2. Sludge should be removed when large suspended particles are observed in the effluent, or when the daily test of settleable solids in the Imhoff cones shows any appreciable increase of settleable solids in the effluent.
3. All inlet and outlet channels, pipes, weirs, valves, etc., should be kept clean and free from accumulations of grease and grit.

Mechanically Cleaned and Plain Settling Tanks with Separate Sludge Digestion

(A) Plain Settling Tanks:

1. The settled solids should be completely removed at frequent intervals, at least twice daily, from the settling tanks to the separate sludge digestion tanks. Mechanical equipment installed for the collection of sludge should be operated for a sufficient length of time before drawing sludge to insure complete removal of the deposited solids.
2. Septic action in the plain settling tanks as evidenced by "gassing" or rising sludge or an appreciable increase of settleable solids in the settling tank effluent should be avoided by prompt and regular removal of sludge to the digestion tanks.

3. Grease and scum should be removed at least daily, using the mechanical skimming device or by using a perforated hand-skimmer and the tanks should be maintained in a clean appearing condition at all times.

(B) Separate Sludge Digestion Tanks:

1. The contents of single tanks should be stirred or agitated at intervals by recirculation or other means to assure proper "seeding" of the fresh solids and to afford rapid and efficient digestion. Such stirring also lessens the chance of acid production, "foaming" difficulties, and excessive scum formation. Where there is surplus capacity or stage digestion this operation is of doubtful benefit.
2. Where heating coils or other adequate means of heating the contents are available, the temperature should be maintained at about 85° F.
3. The amount of fresh solids added daily should not be over one twentieth (5%) of the amount of "ripe" sludge in the tank, on the basis of the dry solid content of each.
4. Care must be used in removing digested sludge to avoid the removal of such a large amount that the ratio of "ripe" sludge to fresh sludge added drops below twenty to one.
5. By concentration tanks or otherwise the solids content of the sludge added to digesters should be as high as is practical to avoid loading the digesters with liquid which reduces the time of the solids in the digesters, creates undue disturbance and chills the contents. This matter is far more important than is generally realized.

Imhoff Tanks

1. Sedimentation Compartment:

(a) Grease and scum in the sedimentation compartment should be removed daily. This is best accomplished where no mechanical means is provided, by the use of a dish-shaped perforated skimmer. Such grease and scum should be promptly disposed of by burying or burning. Where objectionable conditions are not likely to develop, the grease and scum may be placed in the gas vents.

(b) The sides and slopes of the sedimentation compartment should be carefully scraped with a rubber squeegee and all solids pushed down through the slots at least twice a week.

(c) The slot in the bottom of the sedimentation compartment must be kept open and free from obstruction of any kind. At least once a week the slot should be cleaned by the use of a heavy chain drag, taking care to traverse the entire length of the slot.

(d) Failure to carefully follow the foregoing operating procedure will usually result in an effluent of inferior quality and where a trickling filter is used there will be deposits and accumulation of solid material on or in such filter, due to grease, scum or sludge being carried through the tank.

(e) Where the design of the tank will permit, the direction of flow through the sedimentation compartment should be reversed at least once a month, in order to distribute the solids uniformly in the digestion or sludge compartment.

2. Gas Vents or Scum Compartment:

The scum in the gas vent should be broken up at least weekly to afford an easy escape for the gas from the digestion or sludge compartment. Control of the scum may be accomplished by some of the following treatments:

(a) Breaking the scum up with a hoe, rake, or other suitable tool.

(b) Hosing the scum in the gas vents with water under pressure.

(c) Punching holes through the scum at two-foot intervals with a wooden pole.

(d) The scum may be removed and dried in a sludge drying bed if its depth approaches 2 to 3 feet in the vents. Usually it burns readily and if incinerated may create a hazardous flash, due to grease content.

(e) Treatment of the scum in the gas vents daily with hydrated lime at a rate of about 10 lbs. per 1,000 population has been found to be helpful in controlling excessive scum formation and to aid in maintaining the pH value of the digesting sludge.

3. Sludge Compartment:

(a) The height of the sludge in the sludge compartment should be determined at inlet and outlet ends of the tank at least once a month. The use of a pump for this purpose is the most desirable and satisfactory. The use of the plate or disc method is not usually satisfactory. The following are suitable methods for measuring the depth of sludge:

(1) One method involves the use of a pitcher pump provided with a rubber suction hose, weighted on the end and the length marked on the hose at intervals of 2 feet, measuring from the weighted end toward the pump. The hose is gradually lowered through the slot in the sedimentation compartment, meanwhile constantly pumping, and the length of immersed hose, when sludge first comes through the pump is determined. When the sludge elevation is reached, the pump will usually "choke" before sludge appears.

(2) The sludge depth may also be determined by use of an iron plate or weighted wooden block, about 12-18 inches square, attached to a wire or chain lowered through the gas vent. The plate or block will stop when the sludge is reached and the distance from the surface to the sludge level is determined from the graduated wire or chain by which the device is lowered. The pump method is by far the most positive procedure.

(b) Sludge should be removed:

(1) Whenever the sludge depth approaches within 18 inches of the slot in the sedimentation compartment.

(2) In small amounts at frequent intervals rather than in large amounts at longer intervals. Usually some sludge should be drawn every month.

(c) Sludge should be removed at a slow regular rate to avoid the formation of a channel through the sludge in the sludge compartment and the withdrawing of partially digested sludge or the liquid above the sludge.

(d) If sludge does not flow readily, it may be started by:

(1) Agitating with water under pressure through perforated water pipes in the bottom of the sludge compartment, if such pipes are available.

(2) Applying water pressure through hose immersed into the sludge compartment or through the sludge riser pipe.

(3) Agitating around sludge inlet with long rods through the sludge riser pipe.

(e) Avoid withdrawal of all the sludge from the tank. Leave sufficient digesting or "seed" sludge to prevent the difficulties incidental to starting a new or completely cleaned tank. Usually not over half the depth of sludge in the tank should be removed at any one time.

(f) After use the sludge pipes should be flushed out and refilled with water or sewage to prevent the sludge from hardening and clogging the sludge pipes.

4. "Foaming:"

There are a number of possible causes for "foaming" such as industrial wastes like milk or cannery wastes, "mash" or "wine" wastes, drawing out too much sludge at one time, or increased temperatures in the sludge compartment. Foaming is almost invariably associated with an "acid" condition of the sludge and in such cases may be minimized or corrected by treatment to counteract the acidity. However, there is such a thing as alkaline foaming but it is not common.

When foaming occurs, there are a few simple treatments which may under certain conditions remedy or improve the condition.

(a) Relief may sometimes be obtained by drawing some sludge.

(b) Hosing the gas vent area with water under pressure will sometimes help.

(c) Cutting the tank out of service if possible and allowing it to rest will permanently improve conditions.

(d) Paddling the foam with long-handled hoes is also temporarily effective.

(e) Hydrated lime added through the gas vents at daily intervals will frequently correct a foaming condition.

(f) Treatment of the raw sewage with chlorine at rates of 20 to 50 pounds per million gallons will often bring foaming under control.

Trickling or Sprinkling Filters

1. The nozzles should be inspected daily. All clogged nozzles should be cleaned and any broken nozzles replaced.
2. The surface of the filter bed should be kept free from plant growths.
3. The formation of ponds or "pooling" on the surface of the

filter bed may be remedied or prevented by:

(a) Flushing the surface of the filter with a fire hose.
(b) Raking or forking the surface of the filter bed.
(c) Punching holes through the top layer of the filter medium with iron bars.
(d) Heavy applications of chlorine, chlorinated lime or other chemicals for short periods applied directly to the bed surface or in the filter bed influent at the dosing tanks. The treatment is usually most effective and economical if applied to the low night flows of weak sewage.
(e) Operation of units may sometimes be improved by cutting them out of service occasionally for a period of 12-48 hours.

4. Where the design of the filter bed will permit, the presence of large numbers of filter flies may be controlled by periodic flooding of the filter beds. Chlorine application, as for ponding, is also very helpful but not a 100% effective remedy. In flooding the sewage it should be chlorinated to delay oxygen depletion and septic action during the holding period.
5. The distribution piping should be flushed periodically.
6. The underdrains should be flushed out occasionally with water hose or other suitable flushing devices, if the filters are so constructed as to make this possible.
7. Where revolving distributors are installed, frequent inspection of water or mercury seals should be made.
8. Where revolving distributors are installed, the flow from the nozzles should be adjusted so that the flow delivered is proportional to the area covered, i. e., the end nozzle should deliver twice as much as the one half-way out from the center. The center nozzles should deliver very little flow—only thin share for the ratio of area covered.

Secondary or Final Settling Tanks

1. The sludge should be removed frequently to prevent septic action and gasification of the solids which results in discharge of solids with the final effluent. This cleaning is usually necessary at least once a month, or oftener, during the summer season.
2. The depth of the sludge should be determined at frequent intervals by the use of a sludge sounder or other device.
3. The sludge may be disposed of in the same manner as sludge from primary settling tanks, i. e., pumped into primary settling tanks or into separate sludge digestion tanks direct for digestion. In the latter case density of the sludge is an important consideration to perclude the effects of dilution on the digesters.

Sludge Drying Beds

1. Sludge beds should not be filled to a depth of more than 12 inches or to such a depth that the sludge cake cannot be removed within two weeks in good drying weather.
2. The surface of the drying bed should be kept clean and free from all previously discharged sludge. *Never discharge wet sludge upon dried or partially dried sludge.*
3. The surface of the sludge drying beds should be kept nearly level to afford an even distribution of sludge over the surface of the bed.
4. Dried sludge may be used for fill, buried, or spread upon the ground, where it will not be carried into a stream or watercourse by rain.
5. In many communities the sludge is readily disposed of by giving or selling it to nearby farmers for use as fertilizer. This should be encouraged as sewage sludge has been found to have fertility and soil improving values. It is not advisable, however, to use it for the fertilization of crops which are served in an uncooked condition. For best results the sludge cake should be shredded or pulverized before attempting its sale.

Sand Filters

1. The beds should not be used continuously but sufficient time should be allowed between doses for the bed to drain thoroughly and "rest" between applications. Satisfactory operation of a filter bed depends on the presence of oxygen in the bed and therefore opportunity for the entrance of air into the bed must be provided by the "rest" periods.
2. The beds should be periodically cut out of service, allowed to dry and the surface raked or scraped clean.
3. "Pooling" should not be allowed to develop on the beds as this tends to produce septic action, obnoxious odors and an effluent of poor quality. Pooling indicates that cleaning is necessary. Frequently a harrowing is all that is required. Eventually skimming will be required.
4. The surface of the beds should be kept level to afford uniform distribution of the sewage.
5. Weeds, grass, etc., should not be allowed to grow on the beds.
6. The depth of the bed should be maintained by removing during cleaning only the least possible amount of sand. Once a year clean sand should be added to replace that removed during the year.
7. Where natural sand percolation beds are used it is sometimes advisable to shallow harrow the beds after careful removal of all organic deposits.

Chlorination

The purpose of chlorination is to prevent bacterial contamination of streams or other bodies of water, used for municipal or industrial water supplies, irrigation, shell-fish growing, recreation or bathing.

The effective chlorination of sewage or sewage effluents depends upon the presence of adequate quantities of chlorine at *all* times in all portions of the sewage for sufficient time to provide the necessary period of contact between the disinfectant and the bacteria in order that disinfection may be efficient.

The strength of any sewage varies greatly with seasonal changes, with the days of the week and during the hours of the day. The amount of chlorine required varies accordingly.

1. Chlorine should be applied in such quantity that there will be a residual of at least 0.5 p.p.m., as determined by the ortho tolidine test, after 15 minutes contact of chlorine with the sewage or the effluent, depending upon whether pre- or post-chlorination is practiced.
2. The test for residual chlorine should always be made at the time when the sewage or effluent is the strongest or when it requires the largest amount of chlorine for treatment.
3. Weigh chlorine tank each day at the same time to determine the amount of chlorine used during the preceding 24-hour period.
4. The chlorine must be applied *continuously* in the proper quantities.
5. Before connecting a new chlorine cylinder to the control apparatus, blow off some of the chlorine from the new cylinder into the air in order to prevent clogging of the apparatus. Store the empty cylinders apart from the full ones so as to avoid mistaking empty cylinders for full ones.
6. Examine the chlorine apparatus daily and if any trouble is found which cannot be corrected by the operator, notify your superior at once.
7. It is not advisable to draw chlorine from any one cylinder at rates higher than 40 lbs. of chlorine in a 24-hour period, because of the danger of "freezing" and slowing up the chlorine flow. If more chlorine is necessary, two or more containers should be connected and used in parallel.
8. The operator should always have on hand a stock of the usual replaceable parts for the chlorine apparatus and a reserve supply of chlorine cylinders.
9. Leaks in the chlorine apparatus should be promptly repaired to prevent corrosion of the equipment and structures. Such leaks may be detected by the formation of white fumes when tested in the immediate vicinity with the vapors from an ammonia solution. (Household ammonia is satisfactory).
10. During cold weather heating facilities should be provided to maintain a temperature of 60° F. and never less than 50° F., in order to prevent so-called "freezing" in the chlorinator and stoppage of the chlorine flow. It is frequently necesssary to heat the water supply to the tray of the chlorinator to prevent "chlorine-ice" formation.
11. Chlorine is a liquid when under pressure in the cylinders and is an irritating gas which is heavier than air when released. It may produce serious after effects if inhaled. A satisfactory gas mask should be available at all plants where chlorine is handled.

Activated Sludge Tanks

1. Sludge percentage tests (settling for ½ hour a liter graduate) should be run twice daily on the mixed liquor of the aeration tanks, sampled at the half-way point.
2. When the sludge percentage of the mixed liquor exceeds 30% (300 c.c. in the liter graduate), sludge should be withdrawn. Some plants have been found by experience to operate more efficiently at a lower per cent.
3. Excess sludge should be wasted into the raw sewage if primary sedimentation is practiced or wasted directly to digesters or via thickener tanks if these are provided. Such tanks are an important adjunct to the functioning of digesters.
4. Direct drying of untreated sludge results in odor and fly nuisance.
5. For small plants, dissolved oxygen tests on the effluent

from samples taken from the clarifiers should be run daily. B. O. D. and suspended solids tests on the effluent should be run at least twice weekly.

6. Cracked or leaking air diffusion plates should be watched for and quickly repaired.
7. Air and sewage regulating valves should be operated at least once a month to insure against sticking.
8. Bulking is said to occur when unusual amounts of suspended solids pass out with the effluent. It may sometimes be controlled by one of the following practices:
   (a) Increasing the supplied air or reducing the solids carried in the aeration units.
   (b) Continuously adding lime sufficient to bring the pH up to 9.0 (for small plants).
   (c) Adding small amounts of fine clay (for small plants).
   (d) Moderate chlorination of the returned sludge.
   (e) Bypassing the sewage until condition is corrected.
   (f) Eliminating industrial wastes from the sewerage system when these are proven to be causative.

If bulking becomes a chronic problem, the administrative authority should be fully informed and an investigation by a competent sanitary engineer recommended.

9. Air pressure on this diffuser manifold should be recorded regularly, as increase in pressure results in increased power cost.
10. Operation of final settling tanks is similar to operation of primary settling tanks.

Neatness, Cleanliness, Beautification

1. It is very easy for a sewage plant operator to become negligent. The appearance of his plant reflects in most cases his own character.
2. A limited planting of shrubs and trees will add greatly to the appearance of a plant. Most administrative authorities, if properly approached, will provide at least in a small way, for this improvement. Select hardy plants which require a minimum of attention.
3. Paint is an investment. A plant where painting is neglected will soon require expensive replacements. Learn all you can about paint; many conditions require special paint.
4. A set of neat, well-kept records is a convincing argument when an operator is asking for improvements.
5. A clean plant is usually a well-run plant.
6. An untidy plant is a hazard to life and limb. Slippery steps, unused equipment left in the way, can be the cause of a nasty fall.
7. Work around sewage is always subject to health hazard; extra care and cleanliness are, therefore, essential. A first-aid kit should be on hand and used for even minor injuries. Arrange for prompt medical service for more serious accidents.
8. Make a study of the life cycle of flies and mosquitoes. A knowledge of this subject will enable an operator to control with a little thought and effort, most insect nuisances.

Last but Not Least

9. Join and take an active part in your local sewage works association. The journals and the exchange of operating experience with other members is a rich source of progressive ideas.

Acknowledgement—This paper constituted a lecture in the Water and Sewage Tanks Operators Short Course of the 11th Annual Institute of Government at the University of Southern California, Los Angeles

CONTROL OF ACTIVATED SLUDGE BULKING*

By E. E. SMITH,

Superintendent, Water Works and Sewerage, Lima, Ohio

The operation of the Activated Sludge type of sewage treatment plant has the ever present danger of the so-called sludge bulking. Sewage literature abounds with descriptions, reasons for and treatment of this phenomenon. Experiences at the Lima Sewage Treatment Works seems to indicate close correlation between a marked increase in the numbers of bacterial filaments in the aeration units and poor settling of sludge in the final settling tanks, decrease in dissolved oxygen in final tanks, and poor clarification of final effluent. Sludge bulking seems to be the common cause of inefficient and uneconomical operation of activated sludge plants.

During the summer of 1934 when sludge bulking occurred, all previously described remedies were employed. The sewage upon which these remedies were tried was, in common to most sewages of that drought period, unusually strong and high in temperature, with the consequent necessity of efficient purification during the low stream flows.

Experimentation with Chlorine

Sanitary Engineer J. K. Hoskins of the United States Public Health Service had mentioned to the writer some beneficial results to the process following the use of chlorine at the Stream Pollution Investigations Experimental Plant, in Cincinnati. It was decided, therefore, to look into the effects of chlorine gas on the returned activated sludge.

The design of the Lima Sewage Treatment Works was admirably adapted for this particular experiment for the following reasons:

Activated sludge from the final tanks is brought through two separate 12 inch sludge lines from the tank sumps to a sight feed hopper where separate sludge valves control the sludge flow into a 14 inch combined gravity line conveying the sludge 95 ft. to the returned sludge sump. For purposes of chlorination this arrangement permits *good mixing* and a contact period of ten to twenty minutes, depending on the rate of sludge returned. The results obtained from the use of one tank of chlorine, applied without careful control, were so evidently desirable, that arrangements were made for use of W. & T. solution feed chlorinator.

Observations during the treatment of the returned sludge revealed that seven days after the start of chlorination filaments were absent from the sludge. The ratio of *p.p.m. chlorine to each per cent of solids in the returned sludge* is apparently a governing factor in the action of filament removal, because results were not being obtained when that ratio was below 1.00 during the second application of chlorine. No filament removal was noted for the twelve days of low ratio chlorine dosage.

Inasmuch as the last eleven days of application of chlorine during the first experiment and the first twelve days of the second experiment seemed to indicate that chlorine applied below the apparent threshold ratio of 1.00 was without sufficient effect, a further experiment with chlorine was made at ratios of 2.00 or more.

At the Lima Sewage Treatment Works daily microscopical examinations of the aeration tank effluent are made, as well as the usual hourly estimations of percentage of settling solids in the aeration tank effluent. From the indications of these two determinations the chlorine produced a marked reduction of the excessive numbers of filaments.

Economy of the Process

Air requirements have been reduced to little more than the delivery of the smallest size blower, without regard to variations in sewage flow. It may be estimated that air requirements, without the danger of bulking, should not exceed an average of 0.90 cu. ft. per gallon of sewage. As bulking could be expected usually when the air-sewage ratio was reduced below 1.00 to 1.25 cu. ft. per gallon, the ability to use chlorine as above indicated resulted in a net saving.

The application of air has been as low as 0.62 cu. ft. per gal. daily average and as low as 0.78 monthly average during chlorination. Without the ability to correct sludge bulking so readily and effectively with chlorine such low applications of air would have been unwise and impracticable.

[*Excerpts from an article which appeared in WATER WORKS AND SEWERAGE, October, 1935, here reproduced because other plants have subsequently found the Lima scheme of mild chlorination of returned sludge beneficial in holding oxygen in the aeration units and maintaining performance of the activated sludge process on a more even keel in difficult operating periods.]

ACTIVATED SLUDGE BULKING

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A NUMBER of views have been advanced concerning the causes of bulking. The only agreement in respect to these views is the invariable bulking of activated sludge when treating carbohydrate wastes. The more common cases of bulking are encountered when such carbohydrate wastes cannot be detected in strictly domestic sewage. For the explanation of bulking under such conditions the most commonly held view is that underaeration is the factor responsible. However, certain difficulties arise in uniformly applying this explanation to plant observations. The most obvious difficulty in this respect is the fact that a given plant will undergo periods of bulking followed by periods when the sludge settles readily with the same air input. The dry weather flow has been blamed for such anomalies. The indefiniteness of these views is to be attributed to the fact that under plant operating conditions it is difficult to control all factors which must be taken consideration of. The variables that may influence the results are: the change in the strength and volume of sewage, character and the amount of sludge carried, and sewage temperature. These factors could be more readily controlled under laboratory conditions and varied one at a time to determine the effect of a single factor on the sludge index. Unfortunately all previous attempts to produce a bulky sludge have met with failure under laboratory conditions with carbohydrate-free sewage. The reasons for this are at first not obvious, but a closer comparison of the methods of operation at the plant and the laboratory study will make them apparent.

Deficiencies of Laboratory Scale Studies

At the plant the sewage and sludge flow through the aeration tank continuously, whereas, under laboratory conditions aeration is conducted under a batch process. In a continuous flow tank there is considerable short circuiting and core formation whereas in the laboratory mixtures, this factor is completely eliminated. Furthermore, under laboratory conditions if the air supply is reduced proportionally with the volume of mixtures employed, to secure approximately the rate of 1 cu. ft. per gallon, the air would not be sufficient to keep the sludge in suspension. Therefore, it has been convenient to overlook the volume of air utilized and adjust it to flow at a rate required to keep the sludge in suspension. The result has been a consumption of air three to four times as high as under plant conditions. The air has seldom been metered.

In view of the admitted importance of air in the activated sludge process, this has been a serious oversight. The reasoning behind this has been that in aeration tanks, already more air is supplied than can be utilized; therefore, if doubling or tripling the air supply in the laboratory such will have no influence on the results. But the assumption that since most of air supplied is wasted, and that the sludge is obtaining all the oxygen it requires, is open to question. It is conceivable that due to the slow rate of solution of oxygen and the high oxygen demand, there may be a deficiency of oxygen even in the presence of abundance of air. The anaerobic character of sludge deposits in a flowing stream serves as an illustration of how easy it is to have spots of oxygen deficiency in aeration units.

Since it was realized that sludge may not bulk with a single dose of sewage under laboratory conditions, applications of sewage have been made only once daily. Due to the long aeration period obtained with such a procedure the doses have been increased to twice daily, giving an aeration period of 10-12 hours. However, to get even remotely comparable results at least three daily doses should be made.

Devising a Means of Controlling Air Input

From the above discussion it is apparent that air supply is one of the most important factors and that in laboratory work it has not been adequaely taken care of. The specific problem, therefore, was how to reduce the input of air to valves comparable to plant practice and still keep the sludge in suspension. Two possibilities suggested themselves. First, to use mechanical means for agitation and to supply small amounts of air as the source of oxygen; second, to dilute the air with nitrogen and to pass the gas mixture in rates high enough to keep the sludge in suspension. The latter procedure was selected as the most convenient for laboratory application. It was realized at the outset that by this procedure the partial pressure of oxygen and thereby the saturation value of the oxygen in the sludge mixture would be changed but since saturation values are seldom obtained in the activated sludge mixtures this factor was temporarily disregarded.

An apparatus was assembled by means of which gas mixture containing a given percentage of oxygen could be made and stored in a 30-gallon capacity water tank, by adding definite quantities of air and nitrogen as indicated by the pressure gage. The gas mixtures were passed through two pressure reducing valves in order to maintain a constant flow of gas and through needle valves to regulate the flow into sintered glass crucibles fitted into the bottom of the aeration tubes. The actual flows were determined by calibrated glass orifices which produced a differential pressure proportional to the flow. A more detailed description of the apparatus will be published later in the *Sewage Works Journal*.

The operating schedule was on a fill and draw basis with three doses a day. Aearation periods were approximately 6 hours for the two doses and 10 hours for the night dose.

The sludge index values were calculated according to Mohlman by obtaining the volume in per cent of settled sludge after one-half hour sedimentation and dividing it by the suspended solids concentration of the original mixture, in per cent by weight.

Results

When the oxygen content of the air was reduced to 5 per cent and passed through two sludge mixtures at different rates the revealing results presented in Table I were obtained. The highest increase in sludge index took place with the higher sludge concentration and the lowest amount of air. The sludge index values decreased regularly with increasing amounts of air at both sludge concentrations. The initial sludge index values could not be maintained even with the low sludge concentration (975 p.p.m.) and high amounts of air. That, with a still lower sludge concentration the initial sludge index might have been maintained, is indicated by a subsequent experiment where an initial suspended solids concentration of 400 p.p.m. aeration with 5 per cent oxygen in the gas mixture at the rate of 0.96 cu. ft. air per gallon of sludge mixture gave an initial sludge index of 125 after three doses, a sludge index of 122.

Two factors were indicated from these experiments as having an important bearing on sludge bulking when the sewage load factor was kept constant:

(1) Suspended solids concentration in the aeration tank mixture,

(2) The quantity of air supplied.

Sewage Load Factor

The factor of sewage load was investigated as follows: (a) To a portion of activated sludge sewage was applied three times a day, (b) to a similar portion of the sludge sewage with one-third original strength was applied three times a day, (c) to a third portion of the sludge normal strength sewage was applied once a day. The volume of sewage applied in each case was equal. Six such doses were made in each case. Therefore, (b) and (c) portions received exactly the same quantities of sewage while (a) received three times as much sewage. Aeration was accomplished by 5 per cent oxygen gas mixture at the rate of 1 cu. ft. of air per gallon of sewage in 6 hours. The results in Table II indicate that the greatest increase in sludge index occurred with the application of full strength sewage three times a day. Of greater importance is the fact that when equal loads were applied the more frequent application of dilute sewage resulted in a decrease from the original sludge index while the application of strong sewage at less frequent intervals resulted in an increase from the original index.

Discussion

In the July, 1938, issue of WATER WORKS & SEWAGE this author made certain observations on the factors governing the maintenance of dissolved oxygen in the activated sludge process. It was stated that the maintenance of dissolved oxygen was determined by the resultant of supply and demand. The supply is governed by the type of aeration mechanism and the quantity of air supplied. The demand is governed by the strength and quantity of sewage and of the sludge returned. It was further pointed out that sewage does not have a high saturation value nor as rapid an oxygenation rate as pure water. These observations were made from the standpoint of their effect on purification of sewage by activated sludge. Now we are able to apply these same observations to the bulking phenomenon. It is our con-

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tention that bulking is intimately connected with the purification process. If for any reason purification is seriously hampered there will be no bulking. For instance if nitrogen gas is passed through the activated sludge mixture, purification is poor and bulking does not occur. In other words, bulking does not occur in the complete absence of aerobic conditions. Neither does bulking take place when there is more than ample oxygen supply as is indicated by the failure of sludge to bulk under laboratory conditions with unrestricted air supply. Purification in this case reaches the same value in 2-3 hours as under plant conditions within 6-8 hours. It therefore follows that if it were possible to dose with sewage at 2-3 hour cycle throughout a number of days, bulking might be brought about even with air under laboratory conditions. Since this would require a 24 hour attendance it was more convenient to dilute the air supplied with nitrogen gas, deliver an equivalent quantity of oxygen on the basis of the volumes of the mixture treated as under plant conditions, and dose it only three times a day. The results, a few of which are given in this paper, were revealing. There was a definite relation between the volume of the diluted air supplied and the sludge index. Furthermore, the higher the concentration of sludge the higher was the sludge index at a given oxygen input, indicating that for the strength of sewage employed the quantity of oxygen supplied was not sufficient to meet the demand created at the higher sludge concentration. Therefore, when the oxygenation capacity is limited due to mechanical methods of aeration or when economy in air supply is required, the concentration of sludge in the aeration chamber should be reduced.

The strength of the sewage is an important item in sludge bulking when the oxygen supply is limited. With the same amount of load applied the frequent dosing with a dilute sewage resulted in no increase in sludge index while dosing less frequently with strong sewage gave an increase in sludge index and indicating approach of bulking. In plant practice the sludge receives its full load at the inlet end of the aeration tank. The high oxygen demand of the mixture often gives rise to the complete depletion of dissolved oxygen during the early periods of aeration. As purification proceeds the oxygen demand decreases and dissolved oxygen appears in the aeration tank mixture. Tapered aeration is advocated to meet this situation. However, it seems that a more uniform distribution of the sewage in the aeration tank by inlet ports located along the forward part of the aeration tank would more adequately solve the problem by regulating the oxygen demand rather than by increasing the air supply. It is felt that the absence of dissolved oxygen in the early parts of the aeration period may give momentum to sludge bulking from which the sludge may not be able to recover even when the dissolved oxygen reappears. At present it cannot be definitely stated as to how long the dissolved oxygen may be entirely absent or how low the oxygen level may sag without exerting an influence on the sludge index. It is however, quite conceivable that even in the positive presence of small amounts of oxygen in the liquor the sludge itself may undergo a partially anaerobic decomposition due to the low rate of diffusion of oxygen from the liquor into the sludge and high rate of oxygen uptake by the sludge. In other words a certain minimum gradient may be necessary to keep the center or the floc aerobic.

The next implication of the effect of sewage strength on sludge bulking pertains to wet and dry weather flows. Assuming an equal sewage load under these conditions the concentrated character of the sewage during dry weather would tend to increase the sludge bulkiness. This is in accordance with many plant observations. Whether the strength of sewage *per se* plays a role in this respect or whether dissolved oxygen carried by the dilution water is a factor, cannot be definitely stated at present. Artificial dilution of the sewage during dry weather with stream water or secondary effluent (recirculation of effluent) would prove of definite benefit. Returning the secondary effluent would also add oxygen in the form of nitrates. The same purpose is achieved by increasing the volume of returned sludge while maintaining a low sludge concentration in the mixed liquor, e.g., by returning a thinner sludge. Dry weather flow in most localities is associated with high sewage temperature which may also contribute to the difficulties encountered. At such times, due to the high rate of biological oxidation and lower saturation values of dissolved oxygen, the air supplied may not be sufficient to meet the demand.

Beneficial effect of chlorination in controlling slulge bulking reported in some plants, may be due to the reduction of oxygen demand during the initial critical period of aeration thus allowing the maintenance of dissolved oxygen.

How does oxygen deficiency cause the sludge to bulk and what is the relationship between sludge bulking and filamentous organisms? Let us consider for the present only the Zoogleal and filamentous organisms. Bulking caused by excessive amounts of carbohydrates is due to the excessive development of the filamentous organisms to energy yielding materials which they can utilize readily. This type of bulking may or may not be accompanied by oxygen deficiency. Zoogleal organisms are at a handicap in this competition for the food. In the absence of carbohydrates when the sludge bulks due to a deficiency of oxygen the zoogleal organisms are again handicapped because they require a higher amount of oxygen for their development than the filamentous organisms. The result again is the preponderance of the filamentous organisms. Filamentous organisms get the ascendancy therefore both in the presence and absence of carbohydrates but for different reasons. According to this view the ultimate result is the preponderance of filamentous organisms. In other words a sludge that has become bulky from either cause has a greater number of filamentous organisms than a sludge which settles well and the worse the bulky condition the greater the number of filamentous organisms.

Conclusions

The important factor in the bulking of activated sludge with domestic sewage free from detectable quantities of carbohydrate wastes is due to a deficiency of oxygen created by the slow rate of diffusion of oxygen from the liquid into the floc and the high oxygen demand within the floc. The remedies recommended are: (1) Maintenance of sufficiently high dissolved oxygen in the mixed liquor to allow a high diffusion gradient to the floc. (2) Maintenance of dissolved oxygen not only at the outlet but also throughout the tank. This may be conveniently accomplished by distributing the sewage load. (3) Maintenance of low sludge concentration in the mixed liquor. (4) Dilution of the sewage with stream water, recirculation of secondary effluents or returning of large volumes of thin activated sludge. (5) Reduction of the high oxygen demand rate during the initial aeration period by careful chlorination of returned sludge or through other means.

TABLE I

Effect of Different Rates of Application of 5 per cent Oxygen Gas Mixture on the Rate of Bulking at Two Different Sludge Concentrations

		Suspended Solids		Settling		Sludge Index	
	Cu. ft. air/gallon[1]	Initial	After 3 doses	Initial	After 3 doses	Initial	After 3 doses
1	0.72	2245	1995	25	61	110	306
2	1.08	2245	1930	25	50	110	259
3	1.44	2245	2020	25	39	110	193
4	0.72	975	1035	8	23	82	222
5	1.08	975	1040	8	18	82	173
6	1.44	975	970	8	13	82	134

[1]On the basis of air containing 20 per cent oxygen and 6 hours aeration period.

TABLE II

Effect of Strength of Sewage and Aeration Period on the Bulking of Activated Sludge

	Suspended solids		Settling		Sludge Index	
	Initial	After 3 doses	Initial	After 6 doses	Initial	After 6 doses
Full strength sewage 3 times a day	1100	1360	14.0	48.0	127	350
⅓ strength sewage 3 times day	1100	1065	14.0	12.0	127	113
Full strength sewage once a day	1100	1170	14.0	17.0	127	145

LAKESIDE ENGINEERING CORPORATION
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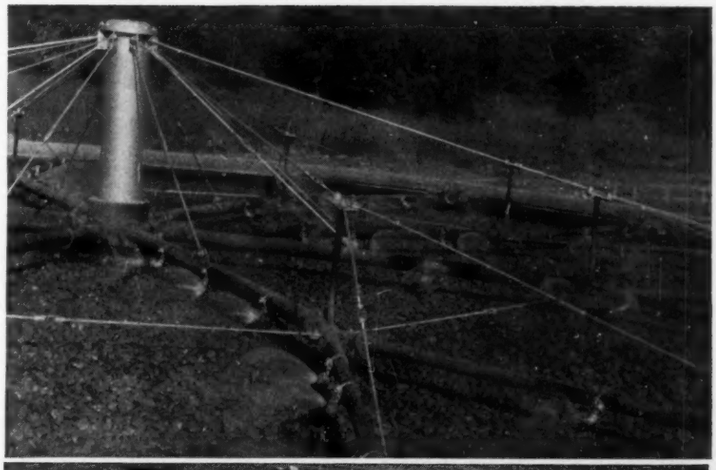
The principle of the multiple arm rotary distributor is well indicated in the illustration at the right. The number of arms, branches and nozzles is varied to fit the needs of the special problem. Further regulation is obtained by adjustment of the nozzles which can be made to discharge directly downward upon the filter, directly upward or in any intermediate position. The angle of discharge can also be changed to any point of the compass, and the orifice nozzles are easily interchangeable in the field. A Lakeside engineer will be present when these units are placed in operation to pan-test the filter bed and make the proper distribution adjustments.



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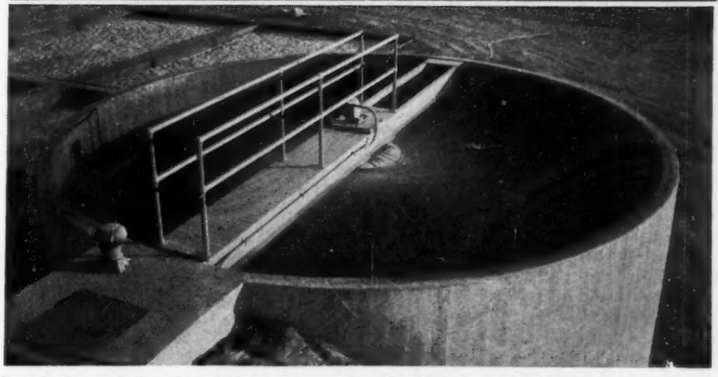
The motor-driven disc distributors range in size from 12" to 34" in diameter and are designed to operate at from 260 to 360 r.p.m., the speed for any given size of filter being constant. The discs are divided into three equal segments each segment being equipped with vanes for dividing the flow of sewage and shunting it uniformly over the filter bed.



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OPERATING FUNDAMENTALS OF THE ACTIVATED SLUDGE PROCESS

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THE properties of activated sludge which are most important to the plant operator are, first, its clarifying or absorptive powers and, second, its oxidizing power.

When activated sludge is mixed with sewage it absorbs the finely divided suspended matter, the colloids, and probably much material in true solution in or on its floc surfaces. If the sludge is then allowed to settle out, the supernatant liquor will be clear instead of cloudy. This clarification action is very rapid and is probably completed in 10 to 30 minutes.

The oxidizing power of activated sludge is generally assumed to be entirely due to biological action. Although its oxidizing action may be some 60 to 130 times faster than the normal oxidizing rates, as measured by the standard B.O.D. test, it is still much slower than adsorption or clarification.[1] The highest rate of oxidation usually occurs when the sludge first comes in contact with the sewage. It then falls off gradually for the next two to five hours, after which it continues at a more or less uniform rate for considerable periods of time.

In any properly functioning plant there is a balance between these two properties. Almost all of the troubles encountered with the activated sludge process may be traced to a lack of proper balance. For example, if biological oxidation proceeds more rapidly than adsorption, the sludge floc become very small and compact. This dense floc does not produce a sparkling clear effluent although nitrification may be very high. Furthermore, some of the floc are apparently broken up into minute particles which do not settle in the final clarifiers, even though the main body of the sludge settles very rapidly. On the other hand, if oxidation lags behind adsorption, the sludge floc will become so light that it will not settle in the final tanks and the sludge will lose much of its clarifying power. Since adsorption is very rapid and almost automatic, the operator's problem is to regulate the rate of biological oxidation so that it just keeps pace with adsorption under the aeration periods prevailing in his particular plant.

There are several conditions under which oxidation will progress more rapidly than adsorption. Probably the most common is over aeration. It is encountered in plants having excessive blower capacity in a few large constant speed machines. It is best to overcome by carrying more sludge in the aeration tanks. A second, but less common, cause of over oxidation is too long an aeration period. The best corrective is to bypass part of the aeration tanks. If that cannot be done, then increase the amount of sludge in the mixed liquor. A third cause of over oxidation may be lack of sufficient "food" in the sewage. The writer encounters such a condition at Grove City during the early spring. At such times our sewage flow is increased by ground water to four or five times its dry weather volume. Most of the excess flow has to be bypassed and hence only one-third to one-fourth as much organic matter enters the aerators as normally. We have found that the admittance (after liming) of digester supernatant to the aerators was quite helpful at that season.

Causes of Oxidation Lag

There are at least six possible causes of oxidation lagging behind adsorption, as follows:

(1) *Inadequate Oxygen Supply:* In any aeration tank (mechanical or diffused air) we have two opposing forces, one, the aerator device injecting air into the mixed liquor, and two, the biological organisms using up oxygen in their life processes. Dissolved oxygen determinations on the mixed liquor give a measure of the excess of the oxygen supply over the oxygen consumption. It is absolutely essential that the rate of supply be at least equal to the rate of consumption, but there is nothing to indicate that any great excess is beneficial.[2] If there is no dissolved oxygen in parts of the aeration tanks then either the oxygen supply must be increased by using more air, or the rate of oxygen consumption must be cut down by reducing the amount of sludge or sewage in the mixed liquor. Naturally sludge reduction is the most general practice.

(2) *Germicidal Wastes:* Since oxidation is entirely biological it is evident that germicidal wastes will stop or retard it. If the germicidal action is due to excessive acidity or alkalinity neutralization with lime or acid will eliminate it. (The optimum pH for biological oxidation is 7.0 to 7.5 although there is little retardation at pH 6.4 to 8.0.[4] If it is due to phenolic compounds or other toxic substances, the only certain remedy is to exclude them from the sewers. In some cases, however, where the concentration of the poison is quite uniform and not too high it may be possible for the sludge organisms to become accustomed to it.

(3) *Excessive Carbon Dioxide:* Carbon dioxide is one of the principal end products of biological oxidation[3,4] and excessive amounts of it are known to be toxic to bacterial activity. Sewage already contains relatively large amounts of CO_2. Although aeration is an efficient means of removing carbon dioxide the rate of its production during the activated sludge process is so great that the net reduction due to aeration may be slight. In such cases it is quite possible that the rate of oxidation is limited by the CO_2 content of the mixed liquor. When such conditions prevail it is logical to apply lime to the inlets of the aeration tanks.[4] Either one of two general schemes may be followed; (a) daily applications of 50 to 300 lbs. of lime per M.G. of daily flow applied in one to four "shots" during hours of peak sewage flow, or (b) continuous lime applications at rates of 300 to 500 p p.m. until such time as the pH at the outlet of the aerators approaches 8.0. The best way to tell whether or not excessive CO_2 is causing trouble is to try the lime treatment. It is fortunate that this treatment can do no harm so long as the pH at the outlet of the aerators does not exceed 8.8, whether or not it does any good.

(4) *Septic Sewage or Sludge:* Septic action not only increases the carbon dioxide but produces other products that retard biological oxidation. Avoid sludge accumulations in sewers, channels, primary or final clarifiers. The return of large volumes of poor quality digester overflow liquor to primary tanks may cause the entire sewage flow to become septic. Frequent sewer flushing may be helpful. Prechlorination at various points along the collection system may be even more helpful. Partial chlorination of the return activated sludge has proved beneficial at some plants but chlorine is a powerful germicide and particular care is required to avoid over-chlorination of the sludge which might destroy its oxidizing power.

(5) *Excessive Grease Content of the Sludge:* If the grease content of the sludge is excessive the sludge particles become coated with a film of grease thus preventing intimate contact with oxygen, even though tests show an abundance of dissolved oxygen in the mixed liquor, hence oxidation is greatly retarded. Wiest's[6] work indicates that the activated sludge process functions satisfactorily when the grease content of the sludge is 5 to 7 per cent but gives considerable trouble when the grease content is around 20 per cent. The writer's experience indicates that 13 per cent grease in the sludge makes for difficult operation while 30 per cent grease causes the sludge to lose its clarifying power and a very inferior effluent results. If the grease content of the sludge is generally excessive then some means of further removing grease from the incoming sewage is indicated. But where the trouble is caused only by periodic shots of mineral oil the writer has found a 25 per cent increase in air for a day following such shots to be helpful.

(6) *Inadequate Aeration Period:* Even under ideal conditions biological oxidation is much slower than adsorption and, hence, there is some minimum aeration period required below which the process will not function. Usually there is nothing the operator can do but bypass part of the sewage flow and ask for more aeration tanks. In some cases, however, short circuiting in diffused air plants has been a factor that could be corrected by proper baffling. Current meter readings at various points may be helpful in designing or locating baffles. In other cases it has been possible to delay major extensions by utilizing part of the aeration tanks for sludge reaeration, thus lengthening the available time for biological oxidation.

Since both the quantity and strength of the sewage varies from hour to hour and day to day, it might be asked, how is the operator to maintain a constant balance between adsorption and oxidation at all times. He can not! In the normal plant oxidation probably falls behind adsorption during the high flow of strong, daytime, sewage and catches up during the low flow of

weaker night sewage. In some plants it is even possible to observe a gradual deterioration of the sludge through the week with recovery over Sundays. It must always be kept in mind that it is only prolonged periods of excessive adsorption that cause serious sludge deterioration, and that several days of excessive oxidation are required for its recovery. The closer the balance is maintained the lower will be the power costs, but the higher will be the laboratory and attendance costs. Therefore more laboratory work is justified in large plants than in small, but some is required in all.

Sewage Input vs. Air Input, and the D. O. Test

Since most if not all of the oxidation occurs in, or on, the sludge floc it should be evident that most of the oxygen is consumed by the sludge. Therefore, it is a serious mistake to attempt to regulate the air input in proportion to the sewage flow. Dissolved oxygen determinations throughout the aeration tanks are the best criterion known for air regulation. If the air is to be varied throughout the day then these tests should be made at various hours throughout the day. If a constant rate of aeration is to be used then the tests should be made at whatever time the dissolved oxygen is at a minimum; this will usually be found a few hours *after* receipt of the peak sewage flow. Samples should be collected from various points between the inlet and the outlet of the aerators. Unfortunately the dissolved oxygen determination, the most important of all operating control tests, can not be made directly on the mixed liquor because of interference from the sludge floc. The accurate determination is extremely difficult and requires special equipment,[7] however tests for routine plant control may be made on samples of supernatant liquor siphoned off from larger samples of mixed liquor collected from the aerators. At Salinas, California,[8] the writer collected 2 liter samples from the tanks and allowed them to stand until sufficient clear water could be siphoned off to fill the small D.O. bottles. Ordinarily 5 to 15 minutes standing sufficed although at times of severe bulking as much as 40 minutes was required. That procedure is open to the objection that the sludge consumes some oxygen during the sedimentation period. However, on several occasions we siphoned off a second sample an hour or two after taking the first one and repeated the D.O. determinations; the decrease in dissolved oxygen in the supernatant over the elapsed time was surprisingly small. Theroux, Eldridge and Mallman[9] recommended the addition of 10 ml. of 10 per cent copper sulphate solution to the 2 liter samples of mixed liquor. The copper sulfate acts as a coagulant, speeding up sedimentation, and at the same time halts biological oxygen consumption. Theoretically, at least, this method is open to the objection that the copper sulfate tends to react with the potassium iodide added after liberating iodine and thus giving results that are too high. Heukelekian uses about half as much 10 per cent sulfuric acid in place of the copper sulfate. The writer has tried all three methods simultaneously at Grove City on several occasions and found little or no practical difference. We use copper sulfate in our routine work.

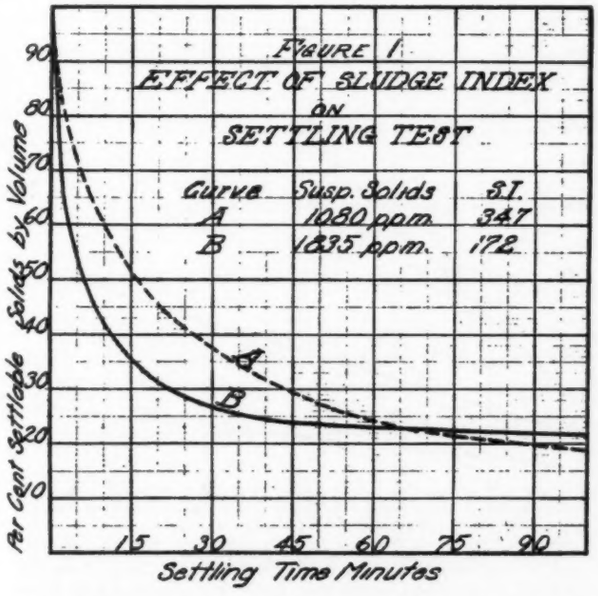

Fig. 1—The Effect of Sludge Density (Sludge Index) on the Volumetric Sludge Settling Test.

Regardless of the method used to separate out the sludge floc the Rideal-Stewart modification of the Winkler method should always be used for determining the oxygen in the small, siphoned samples because of the possible presence of nitrites in the liquor, see "Standard Methods."[25]

Measuring Sludge in Mixed Liquor

We have mentioned increasing or decreasing the amount of sludge in the aerators as a means of controlling the oxydation-adsorption balance. This leads us to the second most important control test, namely, some means of measuring the amount of sludge in the mixed liquor. By amount of sludge we mean *weight* of sludge solids. No universal rule can be given for determining the proper amount. Perhaps 600 to 1500 ppm. of suspended solids in the mixed liquor would cover most mechanical aerators while 1200 to 3000 would cover most compressed air plants. The higher the sludge content of the mixed liquor the faster will adsorption and oxidation progress, but the greater will be the power requirements. If the aeration period is short an increased sludge content will give a higher degree of treatment, but if an adequate aeration period is available almost as good purification can be obtained with a low sludge content and a considerable saving in power may be realized. With a low sludge content organic matter adsorption per unit weight of sludge is very high and hence a very high rate of biological oxidation must be maintained. Therefore, if the sludge content is low, there is more danger of a plant being upset by sudden shots of strong sewage or organic trade wastes.

Standard suspended solids determinations are the only accurate means of finding the actual weight of sludge solids in the mixed liquor. Unfortunately the test requires considerable time and, for small plants, expensive equipment. In spite of these handicaps the test is extremely valuable and should be made at least once a day at all but the very smallest plants. It should be made at the same time each day. The time selected should be such that the sewage flow for the past several hours has been nearly identical with that of the same hours of each preceding day—usually 8 or 9 a. m. will be the most satisfactory time. The writer has followed this practice at Salinas[8], Topeka[10] and Grove City. We governed the daily amount of activated sludge wasted almost entirely by the results of these determinations. This procedure does *not* accomplish the very desirable end of keeping the suspended solid content of the aerators constant at all times throughout the day. It was probably a minimum at the time the peak flow started coming in and at a maximum in the evening when the sewage flow drops off. However, it did serve to keep the *average daily* suspended solid content of the aerators fairly constant. If it is desired to hold the solid content of the aerators constant throughout the day then one of the approximate "short-cut" methods of solid determination (to be described later) may be used as frequently as desired, but the standard suspended solids test should be made daily as a check on the short-cut procedure. After considerable experimentation the writer has concluded that the saving in power made possible by hourly checks of the solid content of the aerators was not sufficient to justify the time consumed in checking, but such a conclusion can apply only to the plants with which he was connected. Anderson, employing a centrifugal estimation, has found the opposite to be the case at Rockville Center.[11,12,13]

Before leaving the subject of gravimetric solids determinations the writer wishes to make a plea for all operators to base their control on *suspended* solids determinations rather than on *total* solids determinations. It is the suspended solids in the sludge that exert the bulk of its oxygen demand. It would be permissible to base plant control on total solids determinations only if the dissolved solids were practically constant. Such is not the case—at Salinas[8] dissolved solids in the mixed liquor, and plant effluent, ranged from 600 to 1500 ppm. under varying sludge conditions; at Grove City the range is 200 to 500 ppm.

Because of the time required for suspended solids determinations various short-cuts have been used. The simplest are the settling tests and these were the earliest tests used. Samples of sludge or mixed liquor are simply collected in liter graduates, allowed to stand for some given time, and the per cent of settleable solids observed at the end of that time. In the early days it was usually customary to carry a volume of about 20 per cent sludge, after 30 minute standing of the mixed liquor. The test is still used and is quite helpful so long as its limitations are kept in mind. Various standing times are used, ranging from 10 minutes to 1 hour or even longer.

The Sludge Index

Attempts to correlate the volume of settleable solids, as determined in this way, with the actual weight of suspended solids in

the sample soon showed that no such relationship existed unless the sludge index[9] was also taken into consideration, see Figure 2. "The sludge index (S.I.) is the volume in cubic centimeters occupied by 1 gram of sludge solids after settling 30 minutes;" it is computed by multiplying the per cent sludge by volume after 30 minutes standing by 10,000 and dividing that product by the parts per million of suspended solids by weight in the same or a similar sample of mixed liquor. The longer the settling test samples are allowed to stand, i.e., the more the sludge compacts, the less the influence of the S.I. on the results of the test and, hence, the closer their approximation to the actual weight of sludge solids present. Figure 1 illustrates this point fairly well. In general the settling test alone can not be relied on except in the smallest plants, and even then only in those small plants that are so amply designed that they are subject to little bulking. In such plants the possible saving in power may not be great enough to warrant the added cost of conducting more accurate determinations.

The Centrifuge Test

Another short-cut is the centrifugal test. This test consists of collecting samples of mixed liquor or sludge in 15 ml. centrifuge tubes and "spinning" them for a given short time (2 to 10 minutes) in an electrical centrifuge. A hand centrifuge will not serve because of the impossibility of always spinning the samples at the same speed.

The writer first heard of this test being used at the Indianapolis plant in 1928. Like the settling test, it is, at best, a volumetric determination. Nevertheless, it has two outstanding advantages over the gravity settling test. First, it is extremely rapid, and second, it compacts the solids more and hence there is better correlation between its results and those of gravimetric suspended solids determinations. The writer has used a 2 minutes spinning period at 2600 f.p.m. at Salinas and Grove City. At both plants we found that the results of this test were greatly influenced by the sludge index, see Figure 3. Setter[10] used a 10 minute period at the same speed and got fair correlation with the suspended solids test so long as the suspended solids exceeded 1000 ppm.; at lower solids concentrations the volume of sediment was too small to permit satisfactory readings. Anderson[15, 11, 12] used a 5 minute period at 1800 r.p.m. at Rockville Center and considers the test very satisfactory although he gives no data to correlate it with suspended solids determinations. If the test is to be used the operator should first make sufficient trials to prepare a graph similar to Figure 3. Once such a graph is available he may determine the sludge index at daily to weekly periods and from that determination and the graph he can select the desirable centrifugal test results for more frequent determinations.

In addition to determining the amount of sludge being carried in the aerators it is desirable to know something of its condition. The sludge index, as previously described, is valuable in this respect. Color, odor, and floc structure are also valuable. Periodic microscopical examinations are useful. After a little experience these tests, or observations, will usually be found adequate for most plants. In some cases the volatile content or dissolved solids content of the sludge may be found helpful.[5] Still better tests require special equipment such as the Odeometer,[14] Oxy-Utiometer,[16] etc.

Tapered Aeration vs. Delayed Loadings

It was previously stated that the rate of oxidation was usually highest when the sludge first comes in contact with the sewage and that afterwards it falls off gradually. If the air is supplied in just sufficient amounts to maintain a minimum dissolved oxygen content at all points in the tanks it will be found that considerably more air is used at their inlet ends than is used at their outlets. This method is known as *tapered aeration*. Since the rates of adsorption and oxidation increase with increased amounts of sludge, tapered aeration is more necessary when a high sludge content is carried. The rates of oxygenation is limited for any aeration device, but is generally lower for mechanical aerators than for compressed air plants,[17] hence the former usually carry less sludge and frequently provide longer aeration periods. At the new Tallman's Island[18] plant provision is made for adding sewage or return sludge at several different points along the aeration tanks, thereby avoiding the necessity of using such high aeration rates at their inlets. In small plants it is possible to reduce the necessity for tapered aeration by returning a large volume of very dilute sludge. Experience has taught many operators that this practice is a good one for small plants in particular. The excess water reduces the oxygen demand of the mixed liquor at the aerator inlets and forces the sludge along the aeration tanks faster, thereby reducing the air requirements at the inlet end and increasing it further along the tanks.

Importance of Prompt Sludge Recirculation

It used to be considered good practice to carry a considerable depth of sludge in the final clarifiers in order to get as high a solid content, and hence as low a volume of, return sludge as possible. Studies[19] have shown that the oxygen demand of such sludge is frequently so high that it is almost impossible to satisfy it by any aerating device. It has also been found[20] that the activity of the sludge was greatly impaired by even comparatively short concentration periods in the clarifiers and that the fresher the sludge the greater was its purifying power; the effect being most noticeable at plants having a short aeration period. Therefore, the rate of withdrawal from final tanks should be such as to remove the sludge as quickly as possible. In large plants where the cost of pumping excess water may exceed attendance, or in plants using sludge reaeration, it is wise to make frequent sludge soundings and to keep the rate of withdrawal at a minimum consistent with rapid sludge removal. In small plants that do not have sludge reaeration this extra attendance is not justified and a very high, constant, rate of sludge withdrawal can be used throughout the 24 hours. When the plant is treating a strong sewage the daily sludge withdrawal may be actually equal to the sewage flow with no ill results and, possibly, some benefit. (At first it might appear that such an increase in volume of sludge return would unduly shorten the aeration period, however, it may be shown mathematically that increasing the rate of return from 20 per cent to 50 per cent (equal sludge and sewage volume) cuts the nominal aeration period only 10 per cent because so much of the liquor in consequence passes through the aerators more than once.)

Most plants are not designed for sludge reaeration. If reaeration is used it is desirable to keep the rate of sludge withdrawal from the final tanks at a minimum, consistent with rapid sludge removal, in order to have the longest reaeration period, *providing it is possible to maintain some dissolved oxygen at all points in the reaeration tank*. If that can not be done then the rate of withdrawal *must* be increased so as to reduce the oxygen demand of the reaerating sludge.

Sludge Concentration Important

To intelligently divide the sludge withdrawal between return and waste it is necessary to make daily suspended solids tests on the mixed liquor, as previously discussed. If these results are below the amount of sludge desired the amount going to waste should be decreased and vice versa. Waste activated sludge should always be concentrated before introducing it into sludge digestion tanks. At most plants the only means of concentration provided is the introduction of waste activated sludge into the

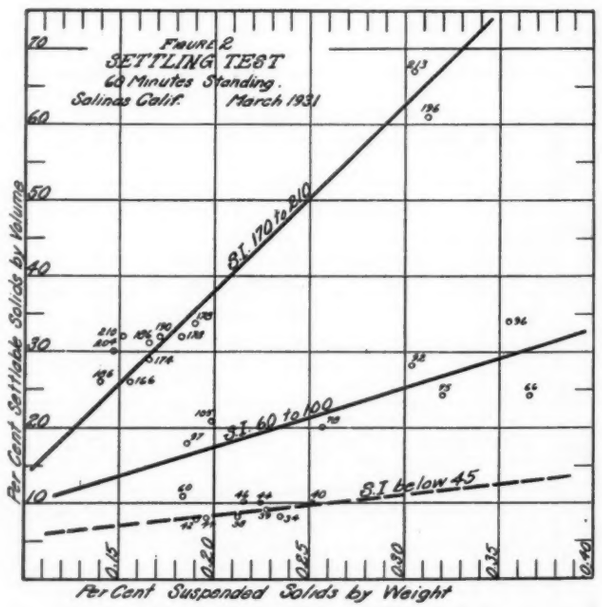

Fig. 2—A Picture of the Lack of Correlation Between Volumetric Sludge Test and the Gravimetric Test. The Necessity of Taking into Consideration the Density and Settleability (Sludge Index) Is Clearly Evident.

primary settlers. It has been the writer's experience that where this method is used better concentrations of primary sludge are obtained by wasting continuously over the 24 hours at a low rate than are obtained by wasting at a higher rate for a shorter time. This method of wasting excess activated sludge has many disadvantages,[21] particularly when the sludge is bulked. A better, though less common method entails the use of a separate tank, termed a sludge thickener, and the use of chlorine.[22, 23] Where a thickener is provided best results are obtained by feeding it with mixed liquor direct from the aeration tanks instead of with sludge withdrawn from the final clarifiers The clear, chlorinated, supernatant from the thickener may be discharged to the incoming raw sewage, the return activated sludge or the final effluent. Either of the first two are preferable because of its beneficial action in overcoming septicity.

Troubles

Now just a few words concerning troubles. Sludge bulking is probably the most common trouble encountered with the activated sludge process. The term "bulking" has been used by some to cover the condition of sludge pouring over the weirs of final clarifiers, but the writer considers that an improper use of the term. A bulked sludge is simply a sludge that, after a given settling period, occupies a greater volume than would a normal sludge containing the same amount of suspended matter by weight. Bulking is best measured by the sludge index[9] as previously described. Whether or not a bulked sludge will pour over the weirs of final clarifiers depends, primarily, upon the design of those tanks. The more generous their design the higher can the sludge index become before the effluent is fouled.

It was previously stated that when oxidation lagged behind adsorption the sludge floc became so light that it would not settle properly, in other words, the sludge bulks. We have given six possible causes of oxidation lagging behind adsorption and suggested means of overcoming them. Any one of those six will cause bulking if not corrected. Certain microscopic, filamentous, growths will cause, or increase, bulking. Sphaerotilus is far the most common organism. Even though the sludge is constantly seeded with these organisms they do not flourish in the sludge if oxidation is keeping pace with adsorption, but if oxidation lags behind adsorption the sludge may become an ideal habitat for profuse growths. Correct the oxidation-adsorption balance and the number of Sphaerotilus will greatly diminish. Other filaments than Sphaerotilus may cause bulking, notably Cladothrix and Leptothrix, but their occurrence is so rare as to warrant no discussion here.

Bulking is not the only cause of excessive amounts of sludge passing out with the final effluent, although it is the most common one. There are two other causes. One is simply insufficient sludge withdrawal, the other is "sludge rising." Rising sludge is most commonly encountered in plants treating sewage high in nitrogenous matter (notably meat packing wastes) where nitrification is quite high. The sludge will settle rapidly in tanks or graduates, but will rise again in from 20 to 90 minutes. The sludge is lifted by accumulations of nitrogen gas. At some plants[24] it has been overcome by keeping the dissolved oxygen in the aerators very low at others[18] it has been found helpful to increase the amount of sludge carried in the aerators.

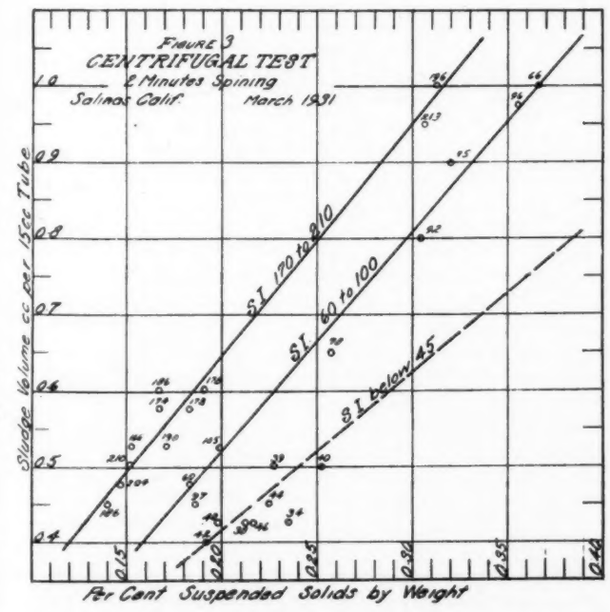

Fig. 3—A Picture of the Less but Evident Effect of Sludge Index Values on Suspended Solids Tests With the Centrifuge.

Digester overflow liquor has caused considerable trouble at several activated sludge plants, among them Grove City. At most plants it is common practice to return digester overflow to the raw sewage, and, in a properly proportioned plant, the liquor will cause little or no difficulty providing its solid content does not exceed 0.2 per cent. If the overflow contains more than 0.5 per cent solids it turns primary clarifiers septic and covers them with gas-buoyed sludge. Under such conditions their effluent is very difficult to treat by the activated sludge process. At Grove City we have an overflow averaging well over 1.0 per cent solids. We add lime to it and turn it directly into the aeration tanks. The proper lime dosage, in our case, seems to be about 1 pound of lime to each 10 cubic feet of liquor. The liquor turns the aerators very dark, detracts from the appearance of the effluent, and unquestionably puts a tremendous burden upon the activated sludge process. However, we have been able to treat most of the liquor in this way although it seriously upset the plant when we attempted to return it to the raw sewage.

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PURGING AIR DIFFUSER PLATES WITH CHLORINE

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The five aeration units at the Irwin Creek Sewage Treatment Plant, at Charlotte, N. C., are of the ridge and furrow type, equipped with diffuser plates. Manometers register the cubic feet of air per minute being delivered to each aeration unit. A master air-meter records the total quantity of air applied.

In the early summer of 1938 the diffuser plates in all the units became so badly clogged that it was impossible, even with two blowers in service, to get enough air through them to maintain proper aeration. All units were then cleaned out, as rapidly as they could be spared from service, and the diffuser plates scrubbed with muriatic acid. This had been the practice since the beginning of plant operation. All but two of the units responded reasonably well to this treatment. Units, No. 1 and No. 5, became clogged again after a few weeks operation. The acid cleaning was repeated in these two but with no better success. The normal average delivery of air per unit with one blower in operation is about 700 to 750 cubic feet per minute. The delivery of the diffusers in No. 5 unit was down to an average of 450 ft. with one blower in service, and with two blowers in parallel an average of 750 ft. could be maintained—(see Fig. 1). Since it was impossible to increase the air delivery in these two units by throttling the other three, and thus increasing the pressure of the air in the header feeding the diffusers; we were in something of a "mess."

At this time the plant load was heavy and the removal of one unit from service for a period long enough to empty and clean was extremely hazardous.

We decided to follow a suggestion previouslv made by L. H. Enslow of the Chlorine Institute. This suggestion was to add chlorine (as gas) to the air headers leading to the diffusers, with the idea that the chlorine would destroy algae growth in the plates, and might attack other clogging materials.

We first viewed this plan with alarm, fearing that the presence of chlorine gas in the air lines might cause corrosion, especially in the small feeder lines. Finally it was decided to try chlorine anyway. A tap was made in the header feeding No. 5 unit and chlorine fed into the air flow at the rate of about 17 lbs. per day.

In Fig. 1 the delivery of the diffusers in No. 5 aeration unit, in cubic feet of air per minute, has been plotted from August 22, 1938, through Oct. 9, 1938. Dotted lines indicate the period during which two blowers were operating in parallel, the solid lines indicating the period during which only one blower was in operation. Note that on Sept. 15 chlorine was fed for about four hours at the 17 lb. per day rate with two blowers operating. After the chlorine was cut off the two blowers remained in service the 18th. At this time one blower was removed from service and on the 19th the chlorine application was continued until the 150 lb. cylinder was exhausted on Sept. 25. The second blower was put on the line on the 24th with the idea that the increased velocity through the plates might help in opening up the pores. On the 30th normal operation was resumed with one blower.

Note the increase in air delivery during the period following the first "shot" of chlorine until the end of the curve on Oct. 9.

Actually, the chlorine brought about an increase of approximately 66% in air delivery with one blower in service and 53% with two blowers in service, as is shown by the curve. Needless to say we were so well pleased with the results that we immediately cleaned No. 1 unit with one cylinder of chlorine getting equally as gratifying results as was the case in the No. 5 unit.

At this date March 1, 1939, the air delivery of the diffusers in both Unit No. 5 and Unit No. 1 is about 750 cubic feet per minute and no detrimental effects from the application of chlorine have been observed.

It is our theory that the action of the chlorine not only cleaned the surface of the diffuser plate but also cleaned the pores *from the inside out,* removing organic matter from interior pores of the plate which could only otherwise be removed by a heat treatment, or long soaking in an acid bath.

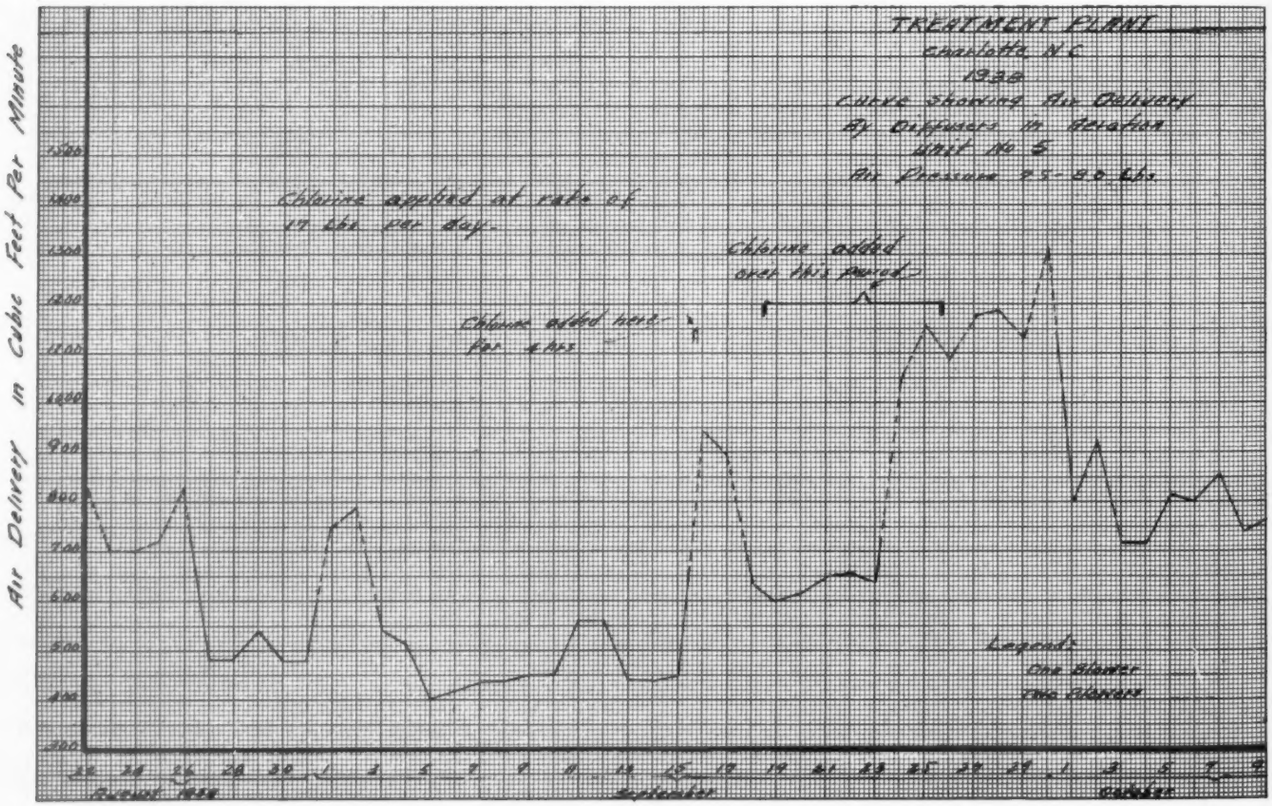

Fig. 1.—Graph Showing Change in Air Delivery Before and After Treatment of Plates With Chlorine Gas, in Situ

CHLORINE DOSAGE CONTROL IN SEWAGE TREATMENT

By G. E. SYMONS, Chief Chemist; J. W. JOHNSON, Asst. Works Supt.; R. W. SIMPSON, Assoc. Chemist
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IN ANY sewage treatment works employing disinfection by chlorination, some control of chlorine dosage is necessary to meet the varying needs. The larger the plant the more important is such control, both from the standpoint of economy and bactericidal efficiencies. With chlorine on the restricted use list of the Federal Government, efficient and non-wasteful usage becomes the more important—and, therefore, there is particular merit in efficient application control in the sanitary field which is enjoying a priority rating—only second to direct defense.

Quite obviously, any system of continuous chlorine dosage control to meet variable conditions will produce the most efficient results[1]. Lacking continuous control, some "programmed step by step method of chlorination"[1] offers the best substitute. The time interval of the steps may be dictated by the size of the treatment works, the variables of chlorine demand and flow, the plant personnel and operation routine, the desired results, and the economy involved.

The effect of all these factors was considered in the development of the control system for the Buffalo Sewage Treatment Works. In a previous paper from this laboratory on "Variations in the Chlorine Demand of Buffalo Sewage"[2] the effect of plant design and pumping schedules on the variations in chlorine demand were discussed.

Buffalo's sewage, etc., arrives at the plant relatively fresh. With the absence of sulfates in the city water supply, there is little or no hydrogen sulfide present in the sewage; and, as has been earlier reported[2], the chlorine demand is on this account relatively low by comparison with that of many other cities.

Still another reason for the low chlorine demand is the high dilution of the sewage. This derives from a high per capita water usage and flow equivalent to approximately 200 g.c.d.

A third reason for somewhat lower demands than observed elsewhere may be due to the technique used in the Bird Island Laboratory for determining chlorine demand. The spot plate technique, which has been earlier reported[3, 4], apparently gives results slightly lower than the technique of the present standard method"[5].

The Chlorination Plant

In order to give a picture of equipment and its relation to chlorine dosage control, a short description of the chlorination department follows: The plant is equipped with five semi-automatic (converter control) solution feed vacuum chlorinators, each capable of delivering 6000 lbs. of chlorine per day. These machines feed chlorine at variable rates which follow all changes in flow rates. Ton containers of chlorine are brought into the building by means of an overhead trolley crane and set in two battery cradles of five containers each. Each battery is connected by a common header from which the liquid chlorine may be drawn to one or more of five steam-coil evaporators. Use of these evaporators is necessitated because the daily chlorine dosage is greater than the maximum possible continuous withdrawal of chlorine in gaseous form from five containers.

Pre-Chlorination Practiced

The chlorine is conveyed in aqueous solution through rubber lined pipes to diffuser nozzles located in each of two sewage conduits. These diffusers discharge into the sewage after a short aeration period some distance ahead of the sedimentation tanks which serve as chlorine contact basins and equalizing units. Complete mixing of chlorine solution in the sewage is obtained, almost immediately with the efficient diffuser installed. Individual evaporators and chlorinators are interconnected but any chlorinator may feed to either sewage conduit. Amounts of chlorine fed are recorded in rates per 24 hours and integrated in total pounds per day by "Telemetric" chlorine flow recorders.

From considerations of the pumping schedules, and the variations in the chlorine demand from hour to hour, it was found advisable to adopt hourly dosage control[2]. This period could be fitted well into a sampling schedule; it was not too long a period to allow uneconomical waste if overdosage occurred, or too long a period for undertreatment in case of underdosage; it was but slightly more than average contact time (estimated to be one-half of the theoretical detention period) within the clarifiers. Changes in rate of sewage flow from hour to hour were relatively of no importance since a pump discharge is practically constant, varying only slightly with the level in the wet well. However, the chlorine demand in p.p.m. may vary considerably from hour to hour. Under these conditions the use of flow converters to control dosage according to flow was only of partial value, because during the morning hours the dose would be below the demand and after the midday peak there would be an overdosage.

A Control System Developed

In the development of a control system, it was necessary to set up certain definitions, techniques, dosage curves, control tests, and factors. These were essential to meet all possible variations of chlorine demand by hours or seasons, and with temperature and storms and industrial wastes as well as with pumping schedules and other operating conditions.

Definitions

Chlorine Demand: The parts per million (mg. per liter) of chlorine required to be added as *chlorine water* (1 mg. Cl_2 per ml.) to produce 0.1 p.p.m. of residual chlorine after 15 minutes contact of the chlorine water and sewage. (Hypochlorite solutions will give lower chlorine demand values and their use does not simulate actual practice in plant operation.)

Residual Chlorine: That chlorine added to water or sewage which is available, after a definite contact time, for reaction with orthotolidine or potassium iodide. It is the surplus of active chlorine added which is not required in satisfying the chlorine demand of the liquid chlorinated.

Spot Test: The determination of the residual chlorine in chlorinated liquids by the addition of 3 drops of orthotolidine reagent to 1 ml. of sample on a conventional laboratory spot plate.

Immediate Chlorine Demand (I.C.D.): The parts per million (mg. per liter) of chlorine required to be added as chlorine water (1 mg. Cl_2 per ml.) to produce 0.1 p.p.m. of residual chlorine when a spot test is made on the sewage immediately after the addition of the standard chlorine water. This value is indicated by the abbreviation I.C.D.

Reagent Factor: The factor used to calculate p.p.m. of chlorine demand from the amount of chlorine water added to the sample. This factor is calculated from the size of the sample (in ml.) used for the determination, and the strength of the chlorine water in mg. per ml. Reagent factor $\times$ ml. of chlorine water = p.p.m. of chlorine demand (C.D.).

Chlorine Demand Rate per 24 Hours: The feeding rate, in terms of pounds of chlorine added per day, required to satisfy the chlorine demand of any given flow of sewage with a particular chlorine demand, i.e., the rate of feed required in lbs./24 hrs. to meet the chlorine requirement for the flow and sewage strength (chlorine demand) existing at any hour. Chlorine demand rates per day equal p.p.m. of C.D. $\times$ flows in m.g.d. $\times$ 8.34. This value can be determined directly from the Multiple Chlorine Demand Nomograph, published in the November, 1940, issue of this magazine[6]. It is an adaptation of a single nomograph for chlorine demand originally developed by Everett C. Handorf[7].

Chlorine Demand in Pounds per M.G.: Lb. per m.g. = p.p.m. of C.D. $\times$ 8.34.

Dosage Factor: The factor by which the chlorine demand (lb. per m.g.) at any particular hour must be multiplied to determine the chlorine dosage rate (lb. per m.g.) for the following hour.

The use of this factor is necessary in the control of the chlorine dosage because the time required for collecting the samples and making the chlorine demand test makes it impossible to ascertain the demand until about 40 minutes after the sewage represented by the sample has been chlorinated. This factor is affected by the time of day, season of the year (temperature of sewage) and storm flows.

Dosage Rates: The number of pounds of chlorine to be added to each million gallons of sewage pumped during the succeeding hour.

The Determination of Chlorine Demand

Approximately a 5 pint sample of raw sewage is collected every hour on the hour at the inlet well. Equal quantities of clarifier influent (approximately 1 minute after chlorine dosage) and of plant effluent are collected within 10 minutes of the raw sewage samples. All three samples are delivered immediately to the laboratory for analysis. Residual chlorine tests are made both on the chlorinated clarifier influent and effluent. If no residual exists in these two samples, the chlorine demand is determined on all three samples approximately 15 minutes after collection, as follows:

(1) *Reagents:* Chlorine water made by passing chlorine gas through distilled water or tap water (if low in carbonates) until 1 ml. contains approximately 1 mg. of chlorine. Standardize by titration with thiosulphate. Orthotolidine indicator solutions as recommended in "Standard Methods of Water and Sewage Analysis," 8th edition[3].

(2) *Procedure:* Measure out 5 portions of sewage to be tested, by completely filling 200 ml. Erlenmeyer flasks which actually hold approximately 217 ml. To the first of these samples add the standard chlorine water, 0.5 ml. at a time (equivalent to approximately 2 p.p.m. of chlorine) mixing by gentle agitation until a spot plate test, using 3 drops of orthotolidine solution and 1 ml. of the sample, give a detectable yellow color[4] but not necessarily a non-fading color. Call this the immediate chlorine demand (I.C.D.).

Using the I.C.D. as the basis of dosage, add reagent chlorine water to the other flasks in increasing quantities, using increments of 0.2 to 0.5 ml. above the I.C.D. Gently mix the contents of all flasks and allow to stand for exactly 15 minutes. At that time determine the residual chlorine in each flask by a spot test. (It may generally be expected that the I.C.D. is approximately 80 per cent of the 15 min. chlorine demand.)

Usually 1 minute is sufficient for the development of maximum color. Use standards made from chlorine water or permanent standards made from copper sulphate and potassium dichromate solutions. These latter must, however, be adjusted to match the hue produced by chlorine water and orthotolidine in a spot plate.

When the maximum color has developed in all spots determine the dosage which has produced 0.1 p.p.m. of residual chlorine or thereabouts. In the absence of standards for comparison, pick the spot with the minimum color. This color is approximately 0.1 p.p.m. In some cases it may be necessary to interpolate in order to determine the amount of chlorine reagent necessary to produce the readable color.

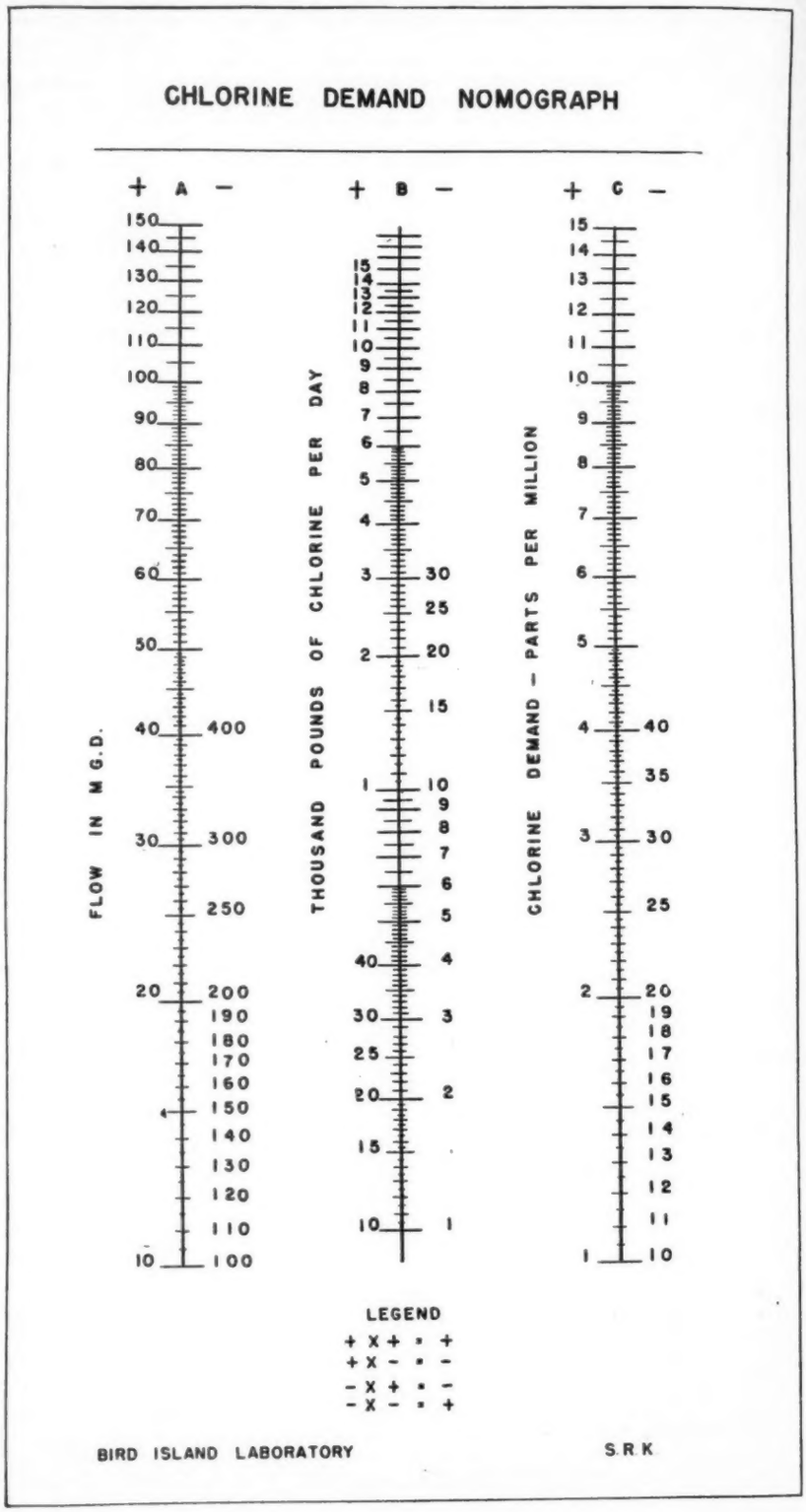
(3) *Calculations:* Calculate the chlorine demand from the amount of chlorine water used and the reagent factor, as illustrated previously. When using 250 ml. of sample; ml. of chlorine solution × mg. of chlorine per ml. × 4 equals p.p.m. chlorine demand (C.D.), or prepared tables may be used for different sized samples and different reagent factors.

For the data records the Chlorine Demand Rate in pounds per 24 hours is determined from the chlorine demand in p.p.m. and the registered sewage flow at the time of the sampling. The Chlorine Demand Nomograph[5] (see cut) is used for this calculation and the resulting value is utilized in weighing the 24 hour average chlorine demand in parts per million.

Directions for Using the Nomograph

In reading the nomograph to determine the chlorine demand or dosage in 1,000 pounds per day from the p.p.m. and the flow in m.g.d., a simple algebraic rule for multiplication must be remembered, viz., plus times plus equals plus, plus times minus equals minus, and vice versa, and minus times minus equals plus. Therefore, if the A+ and C+ scales are used, read on B+, or if A+ and C— are used, read on B—, or if A— and C— scales are used, read B+.

The use of these scales in this manner allows a range of from 1 part per million and 1,500 m.g.d. to 150 p.p.m. and 10 m.g.d. with the thousand pounds per day varying between 0.1 and 1,500. Factors or multiples of 10 extend the range in both directions. By the use of factors or multiples, the readings can always be kept in the area most easily read. A factor of 1,000



will easily convert thousand pounds per day to pounds per day. Scales "A" and "C" can be used for quantities rather than rates per day, in which case Scale "B" reads in quantities rather than rates per day.

The nomograph has other applications than in chlorine application. It may be used to calculate pounds or thousand pounds of solids in sewage, or sludge, from the analysis and the volume, and for other purposes.

This type of nomograph has several advantages, its use is simple, it gives relatively accurate readings, its system and use

TABLE I

FACTORS FOR DETERMINING CHLORINE DEMAND AT ANY HOUR FROM RESULTS OF PREVIOUS HOUR

Season	—Jan., Feb., Mar.—		——April——		——May——		June, July, Aug., Sept.		Oct., Nov., Dec.	
Hour	Per Cent	Factor	Per Cent	Factor	Per Cent	Factor	Per Cent	Factor	Per Cent	Factor
8:00 A.M.	103	1.0	97	1.0	106	1.1	102	1.0	98	1.0
9:00 A.M.	111	1.1	116	1.2	107	1.1	113	1.1	112	1.1
10:00 A.M.	112	1.1	114	1.1	111	1.1	108	1.1	111	1.1
11:00 A.M.	113	1.1	115	1.2	122	1.2	116	1.2	118	1.2
12:00 Noon	102	1.0	111	1.1	110	1.1	102	1.0	104	1.0
1:00 P.M.	100	1.0	96	1.0	88	0.9	105	1.1	100	1.0
2:00 P.M.	98	1.0	98	1.0	97	1.0	99	1.0	102	1.0
3:00 P.M.	102	1.0	100	1.0	93	1.0	101	1.0	103	1.0
4:00 P.M.	106	1.1	98	1.0	109	1.1	100	1.0	100	1.0
5:00 P.M.	100	1.0	106	1.1	97	1.0	100	1.0	103	1.0
6:00 P.M.	96	1.0	92	0.9	98	1.0	97	1.0	99	1.0
7:00 P.M.	96	1.0	100	1.0	100	1.0	100	1.0	96	1.0
8:00 P.M.	92	0.9	98	1.0	98	1.0	97	1.0	95	1.0
9:00 P.M.	100	1.0	99	0.9	95	0.9	95	1.0	97	1.0
10:00 P.M.	94	0.9	95	1.0	98	1.0	94	0.9	94	0.9
11:00 P.M.	104	1.0	95	1.0	100	1.0	100	1.0	102	1.0
12:00 Mid.	94	0.9	97	1.0	96	1.0	98	1.0	97	1.0
1:00 A.M.	98	1.0	97	1.0	98	1.0	102	1.0	98	1.0
2:00 A.M.	98	1.0	100	1.0	98	1.0	98	1.0	97	1.0
3:00 A.M.	96	1.0	100	1.0	96	1.0	96	1.0	97	1.0
4:00 A.M.	92	0.9	94	0.9	93	1.0	93	0.9	93	0.9
5:00 A.M.	97	1.0	94	0.9	93	1.0	94	0.9	100	1.0
6:00 A.M.	97	1.0	90	0.9	97	1.0	94	0.9	95	1.0
7:00 A.M.	103	1.0	111	1.1	103	1.0	102	1.0	96	1.0

can be easily taught to routine control, and it eliminates much calculation where the chlorine demand determination is made frequently.

Determination of Chlorine Dosage

After the determination of the chlorine demand on the 3 samples, the results must be translated into operation control. The data available for this use include the following:

a. The 15-minute chlorine demand of the raw sewage.

b. The residual chlorine or chlorine demand (as the case may be) of a sample of sewage that had been chlorinated 1 minute before the sample was taken and approximately 15 minutes before the test is made.

c. The residual chlorine or chlorine demand of a sample of settled effluent (from the clarifiers) which has been chlorinated approximately 40 minutes (approximate contact or flow through time) before the sample was taken and 55 to 60 minutes before the test is made.

Obviously all of these data represent conditions that have passed and therefore some relation between such data and future hours had to be develepod. The average or normal expected relation of the chlorine demand of one hour to the next for raw sewage was determined from statistical study of the hourly variations in chlorine demand[2]. Inasmuch as these relations vary with seasonal temperatures, it was necessary to develop several series of factors to apply at the different seasons. These are listed in Table I which shows the percentage by which the chlorine demand of the previous hour must be multiplied to obtain the chlorine demand for the hour desired. For practical purposes these percentages were rounded off to factors containing one decimal place as shown.

If there were no other factors involved, it would be possible to calculate the *Chlorine Dosage Rate* in pounds per million gallons for the succeeding hours from these factors and the chlorine demand in p.p.m. of the sample of the previous hour. However, it has been found in practice that there is a seasonal empirical factor that must be applied to these calculations. In the winter time it is found that something less than the calculated chlorine dosage from laboratory tests will satisfy the actual demand of the sewage in the plant and will produce a residual chlorine content in the sewage 15 minutes after dosage. In the summer the reverse is true. A study as to the reason for this empirical factor is underway, but as yet no explanation is available. Therefore, a series of *Dosage Factors* to fit operating conditions has been developed for the various seasons. These are shown in Table II.

Having determined the demand of the raw sewage in p.p.m., then by the use of the various tables the *Dosage Rate* in pounds per million gallons can be calculated for the succeeding hour. The value is telephoned to the operator in the chlorination department, who observes the rate of flow (m.g.d.) in each sewage conduit, multiplies the dosage rate by the flow and sets the chlorinators accordingly for the succeeding hour.

As might be expected, there are exceptions which will not fall into this regular routine. The tests on the chlorinated influent and effluent samples are an aid in checking operation and exceptional conditions. For example, the chlorinated influent sample is approximately 15 minutes old when it is "spotted out" in the laboratory. This is a check on the chlorinator control. for the attempt is made to maintain a 0.1 p.p.m. residual at 15 minutes to effect a proper bacterial kill[3]. Any continued over-or-under-chlorination at this point calls for adjustment of the dosage factor. Likewise, the test on the effluent may indicate a chlorine demand and need for adjustment more than a slight chlorine demand in the effluent indicates a dosage too low to produce effective disinfection.

Special Conditions Affecting Chlorine Control

To meet the special conditions which arise by virtue of any one or more of a number of factors including storms, pumping schedules, and others, special rules have been developed from practical and theoretical considerations.

(1) *For over- or under-dosage*:

a. If the chlorine demand of the plant effluent sample is over 0.7 p.p.m., add the demand in p.p.m. to the raw sewage demand in p.p.m. for the same hour and use the sum of the 2 to determine the dosage rate (lb. per m.g.), for the succeeding hour.

b. If the residual chlorine in the clarifier influent sample is greater than 0.2 p.p.m., subtract the value of the residual in p.p.m. from the chlorine demand of the raw sewage sample at the same hour (in p.p.m.) and use the difference to determine the dosage rate (lb. per m.g.) for the succeeding hour.

(2) *For flows requiring more than* 1 *pump capacity:*

A table of special dosage factors has been developed as follows:

DOSAGE FACTORS

No. of Pumps in Service	First Hour of Higher Flow	Second Hour of Higher Flow	Succeeding Hour of High Flow
During the Period—8 a.m. to 6 p.m., inclusive.			
2 pumps	0.7	0.6	0.6
3 pumps	0.5	0.4	0.3
4 or more pumps	0.4	0.3	0.3
During the Period—7 p.m. to 7 a.m., inclusive.			
2 pumps	0.6	0.5	0.5
3 pumps or more	0.4	0.3	0.3

When an extra pump is cut out of service, this table is used in reverse. If the number of pumps is changed between hours, during the day, recalculation of the dosage rate is made based on these dosage factors. At night, however, if pumpage rates are changed between hours, no adjustment is made in the dosage factor or rate until the following hour. When the number of pumps operating is reduced to 1, after storm flows, the dosage factor is returned to normal.

TABLE II

FACTORS FOR DETERMINING CHLORINE DOSAGE

Seasonal Dosage Factors for the Determination of the Chlorine Dosage for Any Hour from the Analysis of a Sample of the Previous Hour

Season Hour	Jan., Feb. and Mar.	April	May and June and Dec.	July and Nov.	Aug. and Oct.	Sept.
8:00 A.M.	0.9	0.9	1.0	1.1	1.2	1.3
9:00 A.M.	1.0	1.0	1.1	1.1	1.2	1.3
10:00 A.M.	1.0	1.1	1.2	1.2	1.3	1.4
11:00 A.M.	1.0	1.1	1.0	1.2	1.3	1.4
12:00 Noon	0.9	1.0	0.9	1.1	1.2	1.3
1:00 P.M.	0.9	0.9	0.9	1.0	1.1	1.2
2:00 P.M.	0.8	0.8	0.9	1.0	1.1	1.2
3:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
4:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
5:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
6:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
7:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
8:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
9:00 P.M.	0.6	0.7	0.8	0.9	1.0	1.1
10:00 P.M.	0.6	0.7	0.8	0.9	1.0	1.1
11:00 P.M.	0.6	0.7	0.8	0.9	1.0	1.1
12:00 Mid.	0.5	0.6	0.7	0.8	0.9	1.0
1:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
2:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
3:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
4:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
5:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
6:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
7:00 A.M.	0.7	0.8	0.9	1.0	1.1	1.2

It is obvious from this table and system that the chlorine demand of the sewage is not completely satisfied during storms or storm flow periods. This partial chlorination is used for two reasons. First, at the high flows, the amount of chlorine necessary for complete satisfaction may be more than the capacity of the chlorinating equipment, particularly during the first hour, when both the concentration and the total demand in pounds increases.[2] Secondly, inasmuch as the interceptors are designed to carry only 2½ to 3 times the dry weather flow, there are overflows into the river from the intercepting chambers during pronounced storm flows. This storm water is generally considered to be of less sanitary significance although the bacterial concentration is relatively unchanged from dry weather sewage. Inasmuch as excess storm flow and other runoff reaches the Niagara River untreated, it is not practical to fully chlorinate that portion of the storm flow which does pass through the

plant. Data on bacterial reductions[9] show that relatively good disinfection is obtained in storms by this control.

(3) *For sewage having abnormal chlorine demand:*

Occasionally there occur sudden increases in chlorine demand or industrial peak loads.[2] These variations cannot be strictly followed by hourly adjustments of dosage, partly because the analysis, perforce, lags behind chlorination and partly because the changes are so rapid within the hour. If the dosage rate increases less than 25 lb. per m.g. between hours, the normal routine is followed. If the rate increases more than 25 lb. per m.g., and the previous dosage rate was above 60 lb. per m.g., than the determined rate is averaged with the previous hour and the mid-point between the two rates is actually used.

If the demand suddenly decreases, particularly after an industrial peak load, the decrease is followed if it is less than 25 lb. per m.g. If the decrease is more than 25 lb. per m.g. and the previous dosage rate was more than 30 lb. per m.g., then the determined rate is averaged with that of the previous hour and the average of the two is actually used.

Under normal conditions when these changes occur, the maximum dosage to be used is 125 lb. per m.g. and the minimum dosage to be employed is 10 lb. per m.g. The routine tests on the clarifier influent and effluent serve as checks on the efficacy of this system.

(4) *For sewage exhibiting false end points with orthotolidine:*

When color develops on a spot plate by the addition of orthotolidine to raw sewage (without any added chlorine) it is an indication of some industrial wastes which affect the orthotolidine reaction. Bacterial tests[9] indicate that the waste is not chlorine since the bacterial content is unaffected. Therefore, when this condition occurs, compensation for the color must be made in determining the end point in the chlorine demand test.

(5) *For conditions existing when supernatant liquor is drawn from the sludge digestion tanks and returned to the sewage conduits ahead of chlorination:*

Under normal operating conditions the effect of supernatant liquor on the chlorine demand is practically of no quantitative significance, especially if the rate of return is relatively constant. If, however, for some reason the supernatant liquor has a high demand, a sufficient quantity of chlorine is added to the dosage rate to satisfy the demand of the supernatant liquor at the rate it is being returned.

(6) *For conditions existing when "chlorine smoke" is produced:*

"Chlorine smoke" is a thin bluish smoke with an acrid odor. It seems to be a mixture of ammonium chloride and chloramines. The former has been found to crystallize in the ventilating system, and the latter is unquestionably present, as indicated by the pungency of these fumes. It is given off from the conduits within a few minutes after dosage when the chlorine residual is above 0.3 p.p.m. To alleviate this condition when observed, the chlorine dosage to the conduit giving off the "smoke" is decreased until the condition disppears.

Maintenance of Chlorination Equipmnet

Mechanical repair to the chlorinators, or replacement, has been normal. Most of the maintenance has been done by the operators and the mechanics. Of interest are some unusual occurrences and repairs, or cleaning, necessitated thereby.

For example, during the summer months, caddis flies, which are prevalent in the locality, have added to the difficulties of operation. The insects alight in the water of the bell jar tray and are drawn into the apparatus plugging the water lines. The mortality of bell jars was high in the first two years. Uneven pressure exerted on the rim of the jar by the stops being too tight caused strain and sudden differences in temperature between gas and water contributed to the cracking, but greater care and attention to these details has reduced this breakage.

By changing the header line, to which tanks in a battery are connected, it was possible to allow full flexibility in the copper connecting tubes. This rearrangement eliminated replacement due to tube kinking.

Accumulation of chlorine "taffy" in the evaporators has resulted in sudden discharge into the bell jars at times. Some of this material is high in ferric chloride and the fact that pipe lines have been found to contain ferric chloride indicates a possible reverse migration of water. This migration may have occurred due to back pressure in idle chlorinators.

It was observed that chlorine solution was backing up into idle machines from the discharge lines. This occurred apparently because of chipping of the glass ball check valves in the lines from the individual chlorinators. The corrosive solution caused disintegration of the chlorine needle valve stems, thereby requiring more replacement of this item than any other. It has, therefore, been found expedient to keep idle machines operating under a slight vacuum, and frequently to drain all tubes and valve chambers to insure removal of the corrosive solution.

Cleaning of these various items has been by several methods. Carbon tetrachloride of acetone has been used to clean bell jars of "gum"; steam followed by hot air or acetone has been used to clean iron pipe lines carrying liquid chlorine. Pressure reducing diaphragms have had to be replaced because they developed fine pin holes, possibly due to corrosion induced by the suspected reverse migration of water.

In summarizing, it should be pointed out that the details of the Buffalo method of dosage control are subjected to slight revision as chemical, bacteriological, and operating data continue to be obtained, but the fact that the disinfection results[9] have been most satisfactory indicates that the principles of the system are basically sound.

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KEEPING LIME SOLUTION LINES CLEAN

To retard building up of incrustation and depoits, which choke pipe lines conveying lime suspension, the following has been found very helpful at the Richmond, Va., Filter Plant. A program clock at 4 hour intervals opens and closes a flushing valve connected into the line at the inlet end. The line is thereby automatically scoured free of the loosely deposited carbonate and hydrate 6 times daily.

If a scale gradually builds up which the Richmond scheme of water scour will not remove, chlorine water from a chlorinator can be run through for the required period to dissolve or loosen the scale. Chlorine water applied to lime carbonate reacts to produce hypochlorous acid, carbon dioxide and calcium chloride as indicated by the reaction.

$$CaCO_3 + H_2O + 4\,Cl = 2\,HO\,Cl + CaCl_2 + CO_2$$

Pouring chlorine water slowly through a column of ground limestone or marble will demonstrate the reaction and is a well known method of preparing hypochlorous acid. The solution resulting, because of the weakness of the hypochlorous acid produced, has a pH of 8.0 to 8.2.

After the carbonate is all converted, chlorine water will naturally attack metallic solution lines. Lines of rubber hose with jointing made by butting hose ends together *inside* of a short sleeve of larger size hose, or a short section of pipe, provides a very satisfactory all purpose chemical feed line.

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Ammonia Control Apparatus Dry Chemical Feed Devices, etc.

NEWARK, NEW JERSEY

"The Only Safe Sewage Is a Sterilized Sewage"

Atlanta	Chicago	Detroit	Kansas City	Minneapolis	Roanoke	
Boston	Cleveland	Greensboro	Knoxville	Oklahoma City	San Francisco	
Bridgeport	Columbus	Houston	Lexington	Omaha	Seattle	
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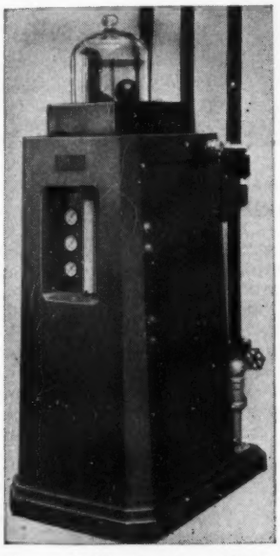
CHLORINATION OF SEWAGE

Of all chemicals used in sewage treatment, chlorine has by far the widest application. From simple disinfection to use as an adjunct to the most involved treatment process, chlorination has for many years been the versatile and valued aid of the man concerned with sewage disposal.

Chlorination is employed to stabilize raw sewage, control odors, increase efficiency of filter beds, prevent filter ponding, improve sedimentation, remove settleable solids, improve sludge digestion, prevent bulking, reduce biochemical oxygen demand, retard putrefaction in the receiving water course, disinfect effluents before discharge and is a necessary adjunct to nearly any process of chemical precipitation.

DISINFECTION

Regardless of the preliminary process of sewage treatment, disinfection of the effluent before discharge is regarded as a necessity. Protection of water supplies, bathing places and shellfish propagation beds, requires efficient disinfection. Chlorination offers the one practical and effective means of sewage disinfection.



Master Visible Vacuum Chlorinator — W&T Visible Vacuum Control is now available in equipments ranging in capacity from .03 to 6000 pounds of chlorine per 24 hours.

ODOR CONTROL

Control of odors from sewage treatment works, long outfall sewers and other disposal plant appurtenances is distinctly a field for chlorination. Neutralization of hydrogen sulphide (the gas responsible for these obnoxious odors) or prevention of its formation by controlled application of chlorine, is not only practical but also satisfactory in results and economy of operation.

B. O. D. REDUCTION

In order to prevent production of odor nuisance, foul appearance and death to fish life in streams receiving the effluents from sewage disposal plants, chlorination for B. O. D. reduction has become increasingly popular. Offering a simple, easily controlled and relatively inexpensive means of supplementing other purification processes during periods of low stream flow or for permanent use at a plant where the dilution factor is low, chlorination has eliminated the necessity for extensive additions to the regular treatment works.

IRON SALTS IN SEWAGE TREATMENT

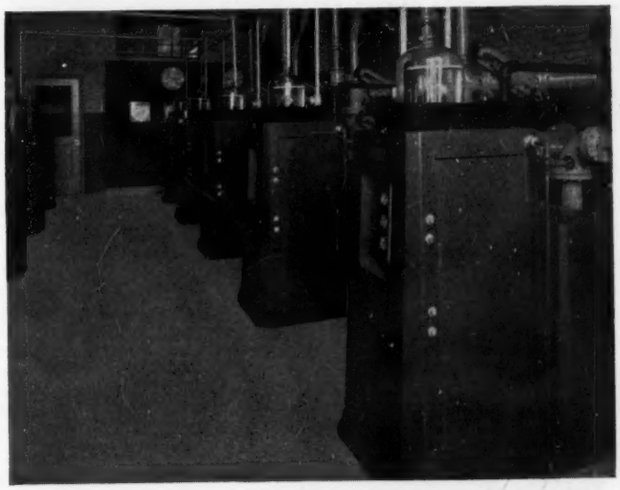
Lowered cost of chemicals and other contributing factors have greatly increased the popularity of iron salts for various uses in sewage treatment, odor control, sludge conditioning, chemical precipitation, etc.

In whatever form this treatment may be adopted, such as the manufacture of ferric chloride at plant site, the addition of ferric chloride or of ferric sulphate directly, or the use of chlorinated copperas, W&T are prepared to furnish the necessary equipment. Complete details on request.

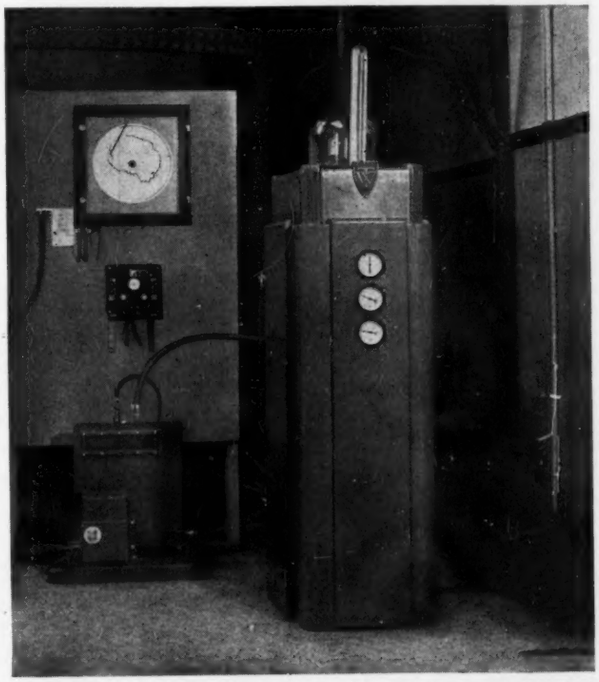
CHLORINE FLOW RECORDERS

Chlorination records form an important log of plant operation and are indisputable evidence that proper application of chlorine was made. Periodic visual inspection will not reveal when equipment may have been temporarily out of service for cylinder change-over, cleaning or any other cause.

The W&T Chlorine Flow Recorders meet the need for continuous automatic flow recording. These Flow Recorders are of two types: the "Direct air transmission type" for continuous recording of chlorine flows, and the electrically operated type which provides indicating, recording and totalizing. The electric type is particularly suitable for use with a battery of chlorinators.



Five W&T Master Visible Vacuum Chlorinators operating at Bird Island Sewage Plant, Buffalo, N. Y.



Panel Mounted Direct Type Recorder with standard Type W&T Visible Vacuum Chlorinator

P.F.T. Pacific Flush-Tank Co.

4241 RAVENSWOOD AVENUE, CHICAGO
NEW YORK CHARLOTTE, N.C.

SEWAGE TREATMENT EQUIPMENT EXCLUSIVELY SINCE 1893

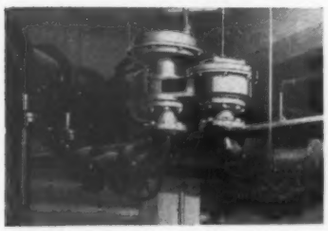
P.F.T. SERVES THOSE WHO SERVE THE NATION

The needs of our country's war preparation are our first concern today. P.F.T. Sewage Treatment Equipment is being installed at scores of cantonments, pilot training fields, naval shore establishments, ordnance plants, war housing projects and other war projects. We are helping, indirectly, to provide the best clothed, best housed, best fed, best paid, best trained military machine in the World!

P.F.T. FLOATING COVERS

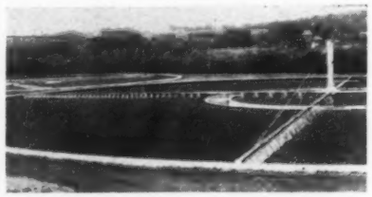
Hundreds of installations including the World's largest, have proved the efficiency and long service life of these units. Available round, square or octagonal in any practical shape for single or two-stage sludge digestion. They accelerate the digestion process, eliminate odors and safely collect gas for heating and power purposes. Detailed in Catalog No. 232.

P.F.T. FLAME TRAPS AND GAS CONTROL EQUIPMENT



To assure safe handling and utilization of digested sewage gas P.F.T. builds renewable element Flame Traps for stopping backfiring from boiler to digester, Adjustable Waste Gas Flame Traps to assure constant line pressure, Waste Gas Burners, Gas Line Condensate Drip Traps, and Pressure Indicating Gauges that indicate pressures in digester and service and waste lines. Detailed in Bulletin 121A.

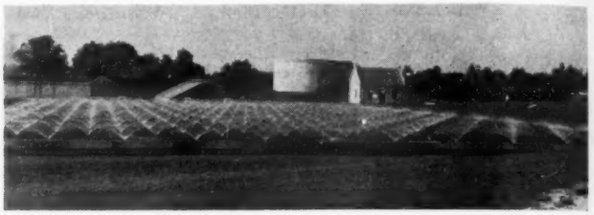
P.F.T. ROTARY DISTRIBUTORS



Provide a practical efficient unit for dosing sewage to filter medium, with minimum area occupied and minimum outlay for piping. They operate at minimum head, frequently eliminating pumping. P.F.T. units feature triple bearings —radial and thrust at top and bearings on guide rollers at bottom; positive mercury seal against normal operating head and patented spreader jets that assure full even coverage of filter bed.

P.F.T. SPRINKLING FILTERS

Where this widely used method of filtering effluents is prescribed, P.F.T. has available several types of circular spray sewage nozzles for application to the risers in the bed. All provide ease of installation and cleaning, and are designed to minimize clogging. Thousands are in successful daily operation. Detailed in Sprinkling Filter Data Book No. 130.



P.F.T. DOSING SIPHONS AND CONTROLS

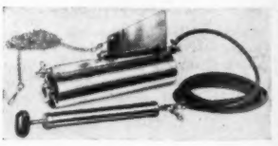
Equipment for predetermined dosing of sewage to rotary distributors, sprinkling filters, sand contact beds, and underground tile laterals is built by P.F.T.

A Twin Tank Dosing Siphon for meting out effluent to sprinkling filter nozzles is shown. This arrangement provides for inflow to one tank while the other is distributing. Detailed in Bulletin No. 130.

P.F.T. CLARIFIERS

New and revolutionary yet destined, we believe, to become a firmly established method of primary sedimentation, the P.F.T. Tray Clarifier is designed to effect the continuous rapid separation of the solids and liquids that constitute sewage and the immediate removal of the clarified effluent. A series of trays or floors, one above the other, are provided, so that the unit is in effect a series of settling stages in a single tank. Bulletin No. 210 gives complete details.

P.F.T. SEWAGE AND SLUDGE SAMPLER



A recently developed device that meets the need for convenient, positive sampling of still or flowing liquids, without disturbing the liquid bodies or contaminating the samples. Cylinder passed through hand hole or laid in open tank has inflatable valves at each end. Hand pump and lowering chain furnished. Side withdrawal cock for easy removal of sample. Described in Bulletin No. 133.

PACIFIC FLUSH-TANK CO. 1892-1942 "50 YEARS of doing one thing well" SEWAGE TREATMENT EQUIPMENT

ELIMINATION OF GAS HAZARDS AT SEWAGE PLANTS

By the ENGINEERING DEPARTMENT
Pacific Flush-Tank Company, Chicago, Illinois

Part 1. General Design Considerations and the Correct Application of Protective Devices

SEWAGE sludge gas, until comparatively recently, an unwelcome source of odor nuisance, is rapidly becoming the long sought "by-product" which will place sewage treatment more nearly on a self-supporting basis. But the utilization of sewage gas as a source of heat and power may prove very costly unless we consider and eliminate the hazards introduced in harnessing this previously wasted source of power.

History

Sewage sludge gas was collected and used for cooking and heating in this country as early as 1915 when C. C. Hommon covered the gas vents of the Imhoff tanks of the Peachtree Plant at Atlanta, Georgia, but the utilization of sewage gas was not considered practical until after the advent of heated separate sludge digestion tanks. Since the first heated sludge digestion installation in this country at Antigo, Wisconsin (1926), the development of this type of sludge digestion with provision for heating and control has made possible a constant supply of sewage gas unaffected by seasonal temperature changes. In present practice, the utilization of this by-product of sewage treatment is one of the most important economic considerations in the design of the modern sewage treatment plant. The safe utilization and nuisance free burning of sewage gas must be considered regardless of the size of the treatment plant.

Uses of Sewage Sludge Gas

Engineers and operators are almost daily finding new uses for sewage sludge gas; as at Old Greenwich, Connecticut, where the operator uses sewage gas to operate the laboratory refrigerator. But the principal uses at the present time are to provide heat for the buildings and to maintain the temperature of the digester, and to develop power with gas engines. The operation of gas engines either to genreate electrical energy, or as prime movers directly connected to pumps or air blowers, is accepted practice in all of the larger treatment plants, and to an increasing extent in moderate to small sized plants also.

The Coney Island plant at New York City, one of the earlier successful installations, is now being extended and will incorporate 10 gas engines developing 6000 H.P. to generate power and operate direct connected blowers. A recent survey[1] indicates that gas engines aggregating over 35,000 H.P. are now in operation in the U. S. Quite a number of operators have written articles indicating that gas engines have paid for themselves in from 3 to 5 years due to the savings in power cost. Probably one of the outstanding examples of a profitable gas engine installation is at Fort Dodge, Iowa, where the city has an agreement with the power company which enables them to buy or sell electrical energy to the power company at the same rate. A 275 H.P. gas engine direct connected to a generator which "floats" on the power line feeds back to the power company's system when the plant demand is less than the output of the generator. During the fiscal year ending March 31, 1941, the city of Fort Dodge received a revenue from the sale of power of $6,620.00. In addition, sewage gas supplied all power for the operation of the plant, including pumping all sewage, compressing air for preaeration, and grease removal, lighting, etc., and the building and digester heating requirements. The cities of Des Moines, Iowa, and Waterloo, Iowa, have a novel contract arrangement whereby they sell to the local gas company all gas in excess of that required for normal gas heating uses. This gas is in turn mixed with city gas by the utility and sold back to the city consumers. The city of Des Moines, during the period from Aug. 1, 1940, to July 31, 1941, received $18,472 from the sale of excess gas. Sewage gas is used at quite a number of plants for providing auxiliary heat in incinerators burning sewage screenings and sludge, or for the joint disposal of garbage and sludge. These few examples indicate the variety of new methods of utilizing the sewage gas, which have introduced new problems which must be considered in connection with sewage treatment plant design and operation.

These problems are receiving considerable attention by State Health Departments and various sewage works associations and insurance underwriters. For example, the joint committee representing the New Jersey Sewage Works Association, the Fire Underwriters, the New Jersey League of Municipalities and the New Jersey State Department of Health, has formulated a set of recommended principles for the safe design and operation of gas handling equipment at sewage treatment plants.[2]

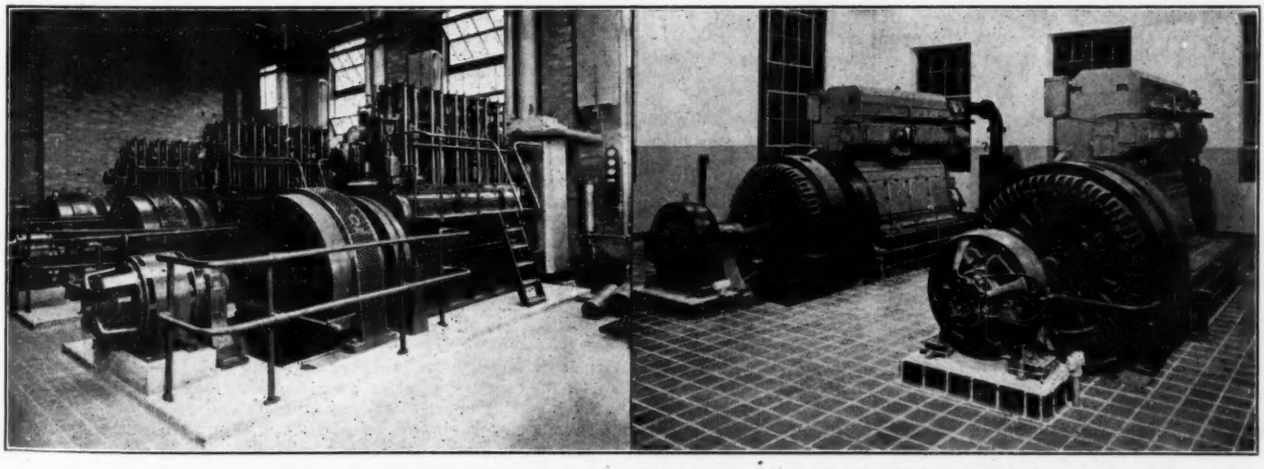
It is the purpose of this paper to better acquaint designers and operators of sewage treatment plants with the hazards involved in gas utilization systems and discuss the principles and applications of the various safety devices. It is only through the full appreciation of the dangers involved and knowledge of means for ample protection that the safe utilization of gas may be assured.

Explosion Hazards

Quite often designers or plant operators will ridicule the dangers in connection with the handling and utilization of sewage gas, saying . . . "It has never happened in any plants that I have designed or operated," or "There are hundreds of plants built without a great deal of regard for protective measures that have operated without any trouble."

But let's review the record—there have been relatively few explosions at sewage plants but the magnitude of those of record (and resultant loss of life) indicate that—"It can happen here."

We might make reference to many reported explosions in sewer systems caused by volatile substances entering the sewer and being ignited, or of loss of life due to toxic or other gases in sewers—but the purpose of this discussion is to consider haz-



Representative Gas Engine Installations, Coney Island, N. Y. (1936 *Worthington*) *and Durham, N. C.* (1935 *Cooper-Bessemer*) *Both having demonstrated their value and dependability of service as amongst the earlier installations.*

Damage to Control Chamber and Imhoff Tanks at Dayton, Ohio, by Explosion

ards more directly associated with the treatment process and gas collection and utilization. A few examples of serious explosions attributed to gas generated in the treatment process include:

Ocean Grove, N. J., April 25, 1915

This explosion and fire in a digestion (septic) tank occurred during the inspection of the treatment plant by a group of municipal officials from another town and cost the lives of two of the visitors and severely burned another.

Causes—Air and gas mixture in tank.
Careless visitor with match.

Moral—Eliminate air-gas (explosive) mixtures.
Do not allow unattended visitors.
No open flames near gas producing tanks.

Woonsocket, R. I., October 2, 1931[3]

An explosion occurred in partially empty digestion tanks which had been entered by two workmen for inspection of a mechanism. The violence of the explosion, which cost the lives of the two workmen, is evident from the photograph in Fig. 2.

Cause—Air and gas mixture in tanks, but method of ignition unknown.

Moral—Recently emptied tanks should not be entered unless completely purged of gas, nor entered during transfer of sludge. Actively digesting sludge should not be transferred from one tank to another which contains air. (Displacement of liquid is safe method.)

Collingswood, N. J., March 5, 1935

A similar explosion occurred in a digestion tank at Collingswood, caused by air being drawn into the tank when sludge was being withdrawn, producing an explosive mixture.

Moral—Keep a positive gas pressure at all times. With a fixed covered tank displace sludge to be withdrawn by new liquid added.

Bristol, L. I., N. Y., February 13, 1946[4]

This explosion occurred in a control house at night when no one was present. It was the consensus of opinion of investigators of the explosion that it was caused by the use of a water seal type of pressure relief of home-made design, from which the water was blown, thus allowing gas to escape into the building. The resultant explosive mixture was assumedly ignited by a coal-fired boiler.

Moral—Eliminate water seal traps. Rely upon specifically designed and tried relief and flame trap units.

Dayton, Ohio ,November 12, 1938[5]

By happening at night between visits of the operator on duty, a violent explosion of sewage gas at the Dayton, Ohio, sewage treatment plant luckily did not injure anyone. The photograph shows the violence of such explosions. This one occurred in the operating gallery between batteries of Imhoff Tanks. Accumulations of gas in the gallery were assumedly ignited by gas heaters in the buildings at the ends of the gallery. Although the damage was so great as to make it impossible to determine the source of the escape of gas, it was indicated that water seal type "running traps" were most probably responsible.

Moral—Eliminate water seal traps.

Other examples of explosions would include:

Marshfield, Wisconsin—where an explosion in a fixed covered digester lifted and shattered the entire top slab. The operator in an adjacent building was hurled to the side of the building and shaken up, but, fortunately, was not seriously injured.

Burlington, Wisconsin

All of the windows of the control building housing the gas boiler and control equipment were blown out when a liquid seal trap lost its water seal. An independent well water supply for the plant necessitated the operation of a pump to provide the water for the plant. In order to economize, the water to provide the water seal on the flame and relief trap was shut off. As a result, gas escaped into the control chamber through the depleted water seal. A coal-fired boiler undoubtedly ignited the mixture. This explosion occurred during the night when no attendant was present.

Iowa City, Iowa

Considerable damage was caused to the pump house at this plant by a gas explosion probably caused by the failure of the thermo-pilot of the gas boiler, allowing unburned gas to escape into the building. No one was in the building at the time of the explosion. Proper maintenance of boiler controls might have prevented this.

Watertown, Wisconsin

An explosion in the pump building due to gas accumulations from a basement sump, which received gassing sludge from the digester, resulted in damage to the building but no personal injury. The possible recurrence was eliminated by covering and venting the sludge sump to the outside atmosphere.

Other Hazards

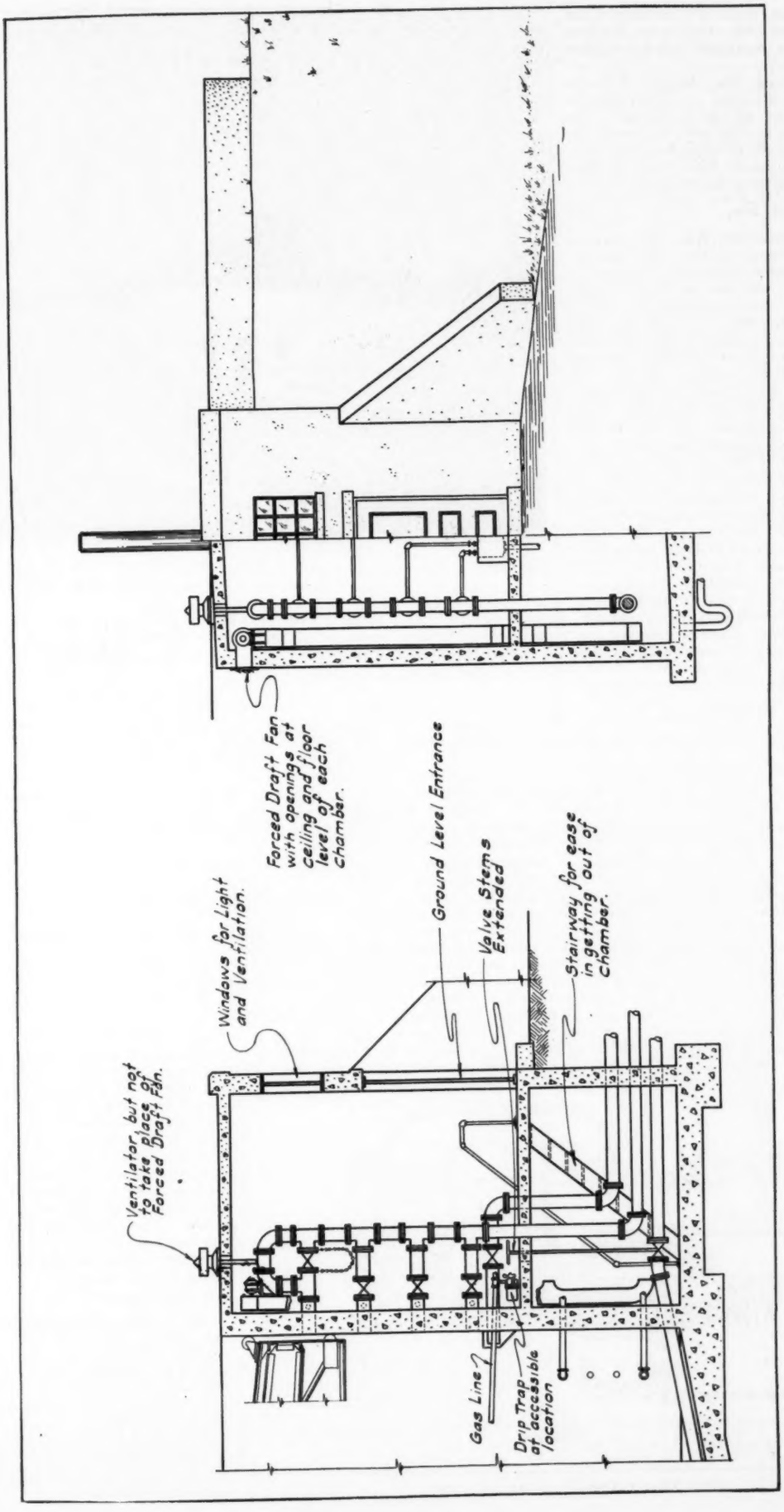
Although explosions are quite spectacular and the damage easy to see, there also has been loss of life due to toxicity or suffocation by gas in chambers. One of the most notable examples, and one at which one of the authors was almost an eye witness, is:

Lima, Ohio, May 4, 1932[6]

A designing engineer sacrificed his life in attempting to rescue a plant operator who was descending a ladder into a control chamber adjacent to a digestion tank and was overcome by gas which had lodged in the chamber. The designing engineer was found to have inhaled even greater quantities of the fatal H_2S (hydrogen sulphide) gas than had the operator. This because of the fact that he was out of breath from running to the rescue when he entered the chamber and was breathing hard and deep.

(The design of digester control chambers discussed later covers means of preventing such tragedies.)

The above examples seem to be the best answer to skeptical designing engineers and plant operators who might be inclined to scoff at the dangers in connection with sewage gas. If a disaster should come, it is well for a designing engineer to be able to say—


Ventilator but not to take place of Forced Draft Fan.
Windows for Light and Ventilation.
Forced Draft Fan with openings at ceiling and floor level of each chamber.
Ground Level Entrance
Valve Stems Extended
Stairway for ease in getting out of chamber.
Gas Line
Drip Trap at accessible location

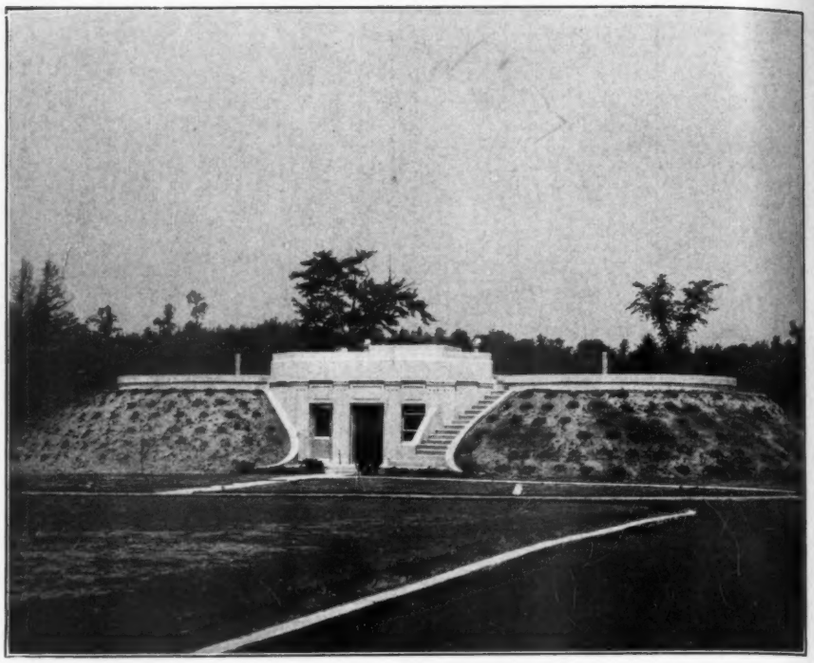
Sections of Control Chamber for Single Digester, Showing Features for Utmost Safety

"All of the protective measures and best design principles known at the time the plant was designed and constructed were provided."

How much better this, than to be critisized or held responsible for great damage or loss of life by having it indicated that known protective devices were not employed. Persons do not scoff at taking out fire insurance because they never had a fire, nor life insurance because they never died.

Composition of Gas

In order to better understand the problems involved in the handling of sewage digester gas we might briefly consider its composition. The constituents of the gas will depend somewhat upon the characteristics of the sewage solids being digested and the conditions of digestion. Essentially, it will consist of a mixture of methane and carbon dioxide, with traces of hydrogen and nitrogen. In some cases, hydrogen sulfide, carbon monoxide, oxygen and traces of other gases will be present. The two main constituents, methane and carbon dioxide, in most cases will make up better than 90 per cent of the gas. It might be interesting to note that the richness of the gas, that is, the percentage of the methane present, is quite dependent upon the condition of digestion. In the initial operation of any digestion tank, gas will be produced which may contain as much as 60 or 70 per cent carbon dioxide. Carbon dioxide is produced in the first or acid stage of digestion and a suitable gas for burning will not be produced until the second (alkaline) stage of digestion has proceeded sufficiently to increase the methane content of the gas. A normal gas will contain from 60 to 75 per cent of methane, and have a heat value of from 550 to 800 B.T.U. per cubic foot.



Digester Control Chamber with Separate Room at Left with Separate Entrance from Outside. Indian Orchard Plant, Springfield, Mass.

Nature of Gas Hazards

Gas hazards might be divided into the following classifications:

(a) *Explosion.*

Mr. L. W. Morrill (2), Secretary of the Gas Hazards Committee of the New Jersey Sewage Works Association, aptly defines the subject as follows: "Any explosion is the result of 4 factors: the presence of an inflammable gas, oxygen, a proper mixture of the two and a source of ignition. Eliminate any one of these and there can be no explosion. At the sewage plant, gas and atmospheric oxygen are, of course, always present, but the gas will not burn or explode unless diluted with oxygen supplying air. Because sources of ignition are so numerous, and to a large extent unpredictable, it is accepted practice to consider them as uncontrollable within limits of absolute safety. Fortunately, one can control the formation of explosive mixtures of gas and air by the simple expedient of keeping them separated."

In a report of tests made by the Underwriters' Laboratories, Inc, it is stated that the flammable range of methane (principal constituent of sewage gas) in air is from 5.6 to 13.5 per cent by volume and that the flame speed and intensity is a function of the concentration, being at a maximum at a concentration of about 9.6 per cent and at a minimum when the concentration of methane is near either of the limits of the range previously mentioned.

(b) *Burning*

When the percentage of gas as compared with air is high or above the limit mentioned above, a "burning" mixture is encountered. Such a mixture is not as dangerous as an explosive mixture since it may be extinguished if encountered. However, sewage plant workers have been seriously burned by an instantaneous flame "puff" that couldn't be termed an explosion.

It is important from the standpoint of flame trap design to take these burning mixtures into consideration as will be discussed under the discussion of "Protective Devices."

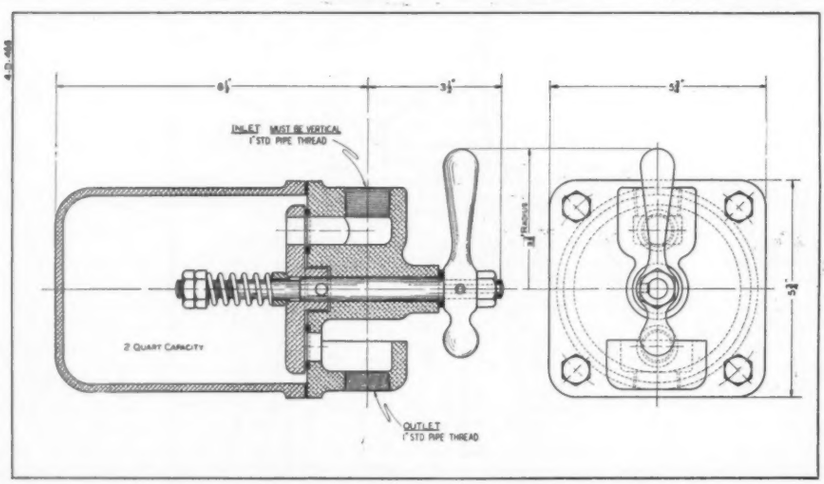
(c) *Toxicity*

Of the minor constituents of sewage gas, hydrogen sulphide (H_2S) is the most important. For the most part it comes from the sulphates in the liquid portion of sewages and industrial waste.

This gas is deadly when present in sufficient concentration as shown by the following:[7]

Fatal in 30 min. or less...	0.06 to 0.10%	(600 to 1,000 p.p.m.)
Severe illness caused ½ to 1 hour	0.05 to 0.07%	(500 to 700 p.p.m.)
No severe effects if exposed for ½ to 1 hour..	0.005 to 0.01%	(50 to 100 p.p.m.)

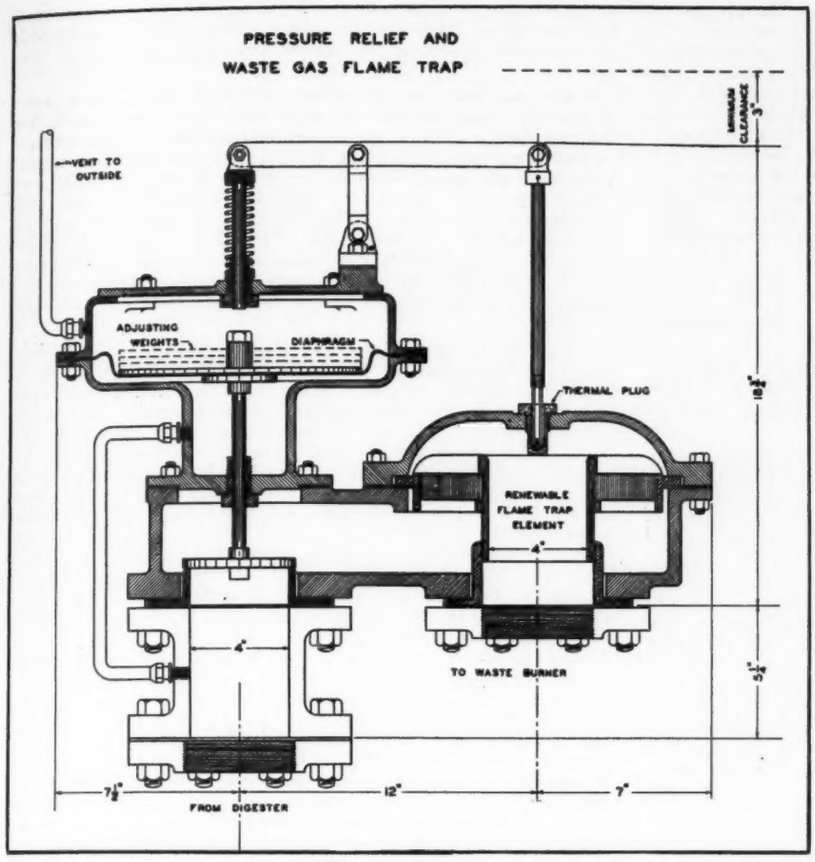
Concentrations of hydrogen sulphide higher than 2,000 p.p.m. (0.2 per cent) cause almost immediate cessation of breathing, resulting from total paralysis of the respiratory center. It is well to reflect upon the fact that hydrogen sulphide has about the same lethal power as hydrogen cyanide (HCN) gas, always considered the most deadly of gases. Although in lower concentrations hydrogen sulphide has a very repulsive odor which may serve as a warning, at lethal concentrations the odor is not so pronounced and the effect of the gas paralyzes the nerve centers so that the odor is not detected by the victim.



Drip Trap (Manually Operated Type)

(d) *Suffocation*

Although the other constituents of sewage gas such as carbon dioxide (CO_2) and methane (CH_4) have not the deadly effect of hydrogen sulphide, they tend to decrease the oxygen content of the air and cause asphyxiation. Man works best and breathes easiest when the air contains about 21 per cent of oxygen. Men breathing air that has as little as 15 per cent of oxygen usually become dizzy, have a rapid heart beat and suffer from headache.



Cross Section of Pressure Relief Waste Gas Flame Trap

Design Considerations

It must be agreed that the preceding discussion of hazards indicates that truly dangerous situations are present when handling sewage gas and that the design of structures and protective devices deserves the utmost consideration by the designing engineer. The designer must consider the probable inexperience of the operator at the start of plant operation and a disregard, leading to carelessness or neglect which may occur later on. He must also recognize that appointment of inexperienced operators may follow, after the first operator, which the designer may have been in a position to instruct effectively.

(a) *Digester Control Chambers*

Until recently the control chambers for digestion tanks consisted, generally, of a small rectangular structure entered from the top through a manhole or steel cover. Loss of life in such structures such as that reported for Lima, Ohio, under "Examples of Other Hazards," has caused engineers to give more consideration to the design of control chambers, and State Sanitary Engineers to make recommendations on minimum requirements for safe design. Some of the elements of a proper control chamber design include provision for the following:

Ground Level Entrance and Convenient Access

Control chambers adjacent to digestion tanks, or chambers which contain gas carrying lines and devices, should have convenient ground level access. It should not contain any manhole steps or ladders but in case access is required to another level, standard stairs or "ship type" stairs, at least, should be provided. With such an arrangement an operator who becomes partially overcome by gas, has a good chance of crawling out of the chamber on hands and knees, while the additional exertion of climbing a ladder, even if possible, would increase the amount of toxic or asphyxiating gas he was breathing and lessen the chance of escape. Rescue operations are also simplified. Windows should also be provided for light and ventilation.

It is also well to design those portions of chambers which lie below the elevation of the ground level entrance so that the operator need not enter such portions in normal operating routine. Valve stems can be extended to the main floor for controlling any valve in the lower portion. The lower portion of such chambers should not be entered unless a companion is present and remains in the upper portion, or unless tests indicate ample safety in entering. Both are preferable.

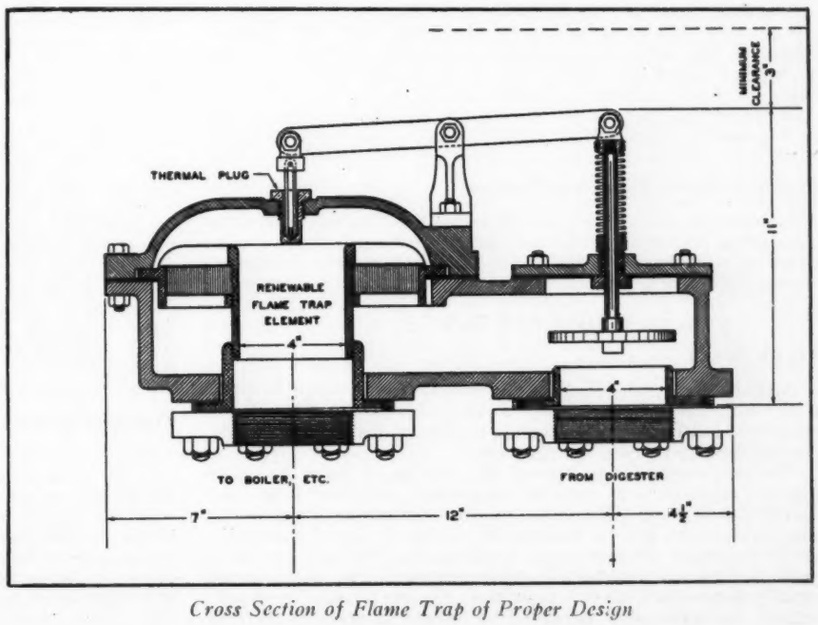
Forced Draft Ventilation

All control chambers where gas might escape or accumulate should be provided with a forced draft fan arranged so that an intake is placed at the floor and ceiling of each floor level. (See cross sections shown herewith.) Such fans should have sufficient capacity to completely change the air in the chamber every 2 or 3 minutes. Fan motor should be wired to a switch at the *entrance* to the chamber, which switch also controls the lights so that the operator must put the fan in operation when he turns on the light on entering the chamber. Natural draft ventilators are not satisfactory due to limited capacity and the fact that some of the gases, notably carbon dioxide, are heavier than air and are not removed from the lower portions of chambers except by forced draft.

A suitable gas mask (with canister sealed off) might well be kept in the control chamber so that it will be available, if needed. The hose type mask is always the safer because no cannister mask is protective in the absence of oxygen.

Separate Gas Control Building

With the increasing attention given to the dangers of sewage gas about the treatment plant, some State Health Departments



Cross Section of Flame Trap of Proper Design

and insurance underwriting boards are recommending the use of a separate isolated building, built entirely above ground level, to house flame traps, meters, boilers and other gas appurtenances. At Green Bay, Wisconsin, the State Board of Fire Underwriters required all gas meters, flame traps, gas compressors and controls to be placed in an isolated chamber *accessible only from an external ground level entrance.* It is possible to accomplish practically the same degree of protection, however, by designing a separate room, as a part of the control chamber adjacent to the digester, to house gas appurtenances. Such a room should have an entrance to the outside, independent of the entrance to the control chamber, and there should be no direct communication between the two chambers.

Digestion Tanks

It is well to repeat for emphasis a previously made statement that—

"ONE CAN CONTROL THE FORMATION OF EXPLOSION MIXTURES OF GAS AND AIR BY THE SIMPLE EXPEDIENT OF KEEPING THEM SEPARATED."

The simplest method of keeping air out of a digestion tank is by keeping the gas within the tank under the classification of a watertimes. In normal operation this condition is assured in the case of floating cover installations, since the unit floats upon the liquid in the tank and lowers when the liquid level is lowered by removal of sludge or liquor, thereby eliminating any space which must be filled up by air or liquid.

In the operation of fixed covered tanks not connected to a gas holder of ample capacity it is necessary to add liquid to the tank whenever sludge or liquor is withdrawn so that the liquid level in the digester is not lowered to a point where the gas is no longer under pressure. (1) (8) (9)

Pressure and vacuum reliefs on digestion tanks, installed to safeguard the structure, are described later. They should be provided with flame trap protection, but in any event the structure should be designed to be strong enough to resist failure under expected vacuum and pressure loads even if the unit fails to come into operation.

Gas Piping

As related to the prevention of explosions, the following general considerations should enter into the design of gas piping systems:

The gas piping system should be a closed system *without any portions which are not as strong as the pipe itself.*

Water seals of any type should not be allowed in the gas system due to the danger of gas leakage from the system if the water evaporates or is blown out. Also, the dangers of freezing must be considered. Float type of automatic drip traps come under a positive pressure at all seal traps, since the needle valve control has been known to be held open by sediment, thus allowing the water to drain from the unit and allowing gas to leak out.

Complete protection can be obtained from a manually operated type of drip trap as shown in the drawing. With this type of trap it is impossible for gas to leak out into the control room or building, since the inlet to the trap is automatically closed when the drain is opened.

Manometer gauges should be arranged so that they are vented to the outside atmosphere in case of breakage of the manometer tubes.

Explosion Proof Electrical Devices

Any motors or switches or other electrical devices located in gas control chamber should be of an explosion proof type designated as suitable for Class I, Group D, Hazardous Locations. Tools used about a digester should be of non-sparking nature.

PROTECTIVE DEVICES

Flame Traps

Basically, any flame trap to be effective must serve to positively stop the passage of any flame or explosion. The flame trap should also be designed with a minimum of restriction to the normal flow of gas through the unit.

The simplest device to prevent the passage of flame is a wire gauze screen such as used in connection with the long used Davy miners' lamp. The value of such a flame resisting device placed in a gas line is questionable. This is true because the possibilities for dissipation of heat are limited and, on being subjected to a continued burning mixture, the gauze would quickly become hot enough to reignite the gas on the "protected" side of the gauze thus defeating the whole purpose of the unit. A metal gauze of this type would not be strong enough to resist the intensity of explosion pressures which might be developed, the explosion rupturing the gauze and causing failure of the unit.

Water seal flame traps also have been used with a false sense of security. Experiments with water seals in excess of 12 inches have resulted in failure to prevent the passage of flame with an explosive mixture of gas and air. It was observed that as the bubbles of gas passed through the water a series of small explosions occurred, successively igniting the bubbles of gas until reaching the supply pipe. Whatever safety a water seal type of trap may afford is naturally lost if the water seal is not maintained. The water seal type of flame trap presents no protection against explosion in the system, since the explosion pressure developed would blow out the sealing liquid and pass right through the unit.

A properly designed flame trap must provide flame protection against sustained burning within the unit, which may occur with a burnable mixture of gas and air. Likewise, against explosion flash-backs with excessive explosion pressure, which may occur with an explosive mixture of gas and air. The flame trap element should be of a material to resist the corrosive action of sewage gas and should be so arranged to provide a multitude of passages small enough to prevent the passage of flame and long enough to assure the dissipation of heat caused by the flame burning on the surface of the element. It has been found to be practically impossible to design a flame trap element which will indefinitely withstand the temperature of internal burning on the surface of the element. Therefore, to provide positive protection against continued burning mixtures it is necessary to provide means to automatically shut off the gas supply. A thermal element should be located near the burning zone of the flame trap to release and positively close off the gas supply. The passageways of the element should be vertical and unobstructed, assuring proper drainage of moisture, freedom from clogging due to impurities in the sewage gas, and passage of gas with a minimum of restriction. The flame trap element should be readily accessible for inspection and servicing. The entire flame trap unit should be designed to withstand explosion pressures which may be expected and, therefore, should be designed to be as strong as the piping system, which will normally withstand pressures up to 125 lbs per square inch.

Pressure Relief Units

The normal gas system should provide means to allow gas produced in excess of the rate of use to go automatically to waste. To maintain close control of the operating pressures within the gas system, the pressure relief should be of the diaphragm actuated type, providing for adjustment of relief pressure by adding or removing weights from the top of the diaphragm. The diaphragm housing chamber should be provided with a vent to outside atmosphere to preclude any possibility of gas escaping into the building in the event of a diaphragm failure. This pressure relief unit is generally found in a combination unit incorporating the flame trap, which provides protection against entrance of flame from the waste gas burner.

Each digestion tank should be provided with means for automatic release of gas at the digester. In case of a stoppage in the gas line, due to settlement and collection of moisture or other causes, proper pressure relief valve with suitable flame trap protection should be provided to allow the gas to escape without danger to the digester. The flame trap element for pressure relief, to allow gas to escape to atmosphere, may be designed to dissipate heat by providing a sufficient exposed and unrestricted surface of the flame trap element. In addition to the pressure relief on the digester, provision should be made for the relief of possible vacuum within the digester. Thus will be prevented structural failure in the event material is drawn out of the digestion tank to an extent which lowers the liquid below the safe operating level. Positive flame trap protection must also be provided, to assure that no flame may enter the digester when the unit is acting to relieve vacuum by allowing air to enter the tank.

Explosion Reliefs

Explosion reliefs have no place in the sewage gas utilization system. Any explosion relief must be so placed that it will release gas to outside atmosphere and, therefore, must in most cases be located at some distance from the source of the explosion. It is questionable that the operation of any relief so located would be effective. This statement is made because the speed of the explosion would undoubtedly carry the explosion pressures through the system before the relief valve could function. The source of explosion hazard can and should be elimi-

nated by the proper location of adequate flame trap protective devices.

Gas Meters, Boilers

Gas meters should always be placed on the protected side of flame traps and should be designed to withstand the same pressures as other portions of the gas system. Gas fired boilers should be provided with adequate thermo-pilot controlled snap action shut-off valve and high temperature shut-off, both operating to control the main gas supply.

Location of Protective Devices

Properly designed flame traps should be provided as close as practical to each point of flame hazard. The closer the flame trap to the source of flame, the more effective it will be in limiting the intensity of the explosion. Tests, conducted by the Underwriters' Laboratories on flame traps for use with sewage gas, have indicated that the intensity of the explosion pressure increased as the size and length of the pipe between the source of flame and the flame trap increased. To limit the intensity of the explosion pressures, *flame traps should be located within 25 feet of the source of flame.* By isolating and providing adequate flame protection for each source of flame hazard, the gas system can be made safe. Protection must be provided for all units burning with open flame such as boilers, waste gas burners, pilots, incinerators, etc. And internal combustion gas engines present a real hazard because of back firing. Any open end pipe such as a waste pipe from pressure relief, even though burning is not contemplated, should be provided with flame protection.

The operator at Lincoln, Nebraska, had an interesting experience in connection with the pressure relief valve on one of his digestion tanks. Lightning struck and ignited the gas being released through one of the pressure reliefs on one of the digesters. The gas burned on the surface of the flame trap element until the operator extinguished the flame. The flame trap element on this unit was adequate and prevented what otherwise might have proved serious consequences.

Part 2—Piping, Storage and System Operation

Design of the Gas System

GAS pressures available to operate sewage gas systems are quite limited. Quite often the maximum pressures available at the digester will be limited to 5 in. or 6 in. of water column. With 2 in. or 3 in. required to operate a gas fired boiler it is imperative that losses in flame traps, gas meters and other control devices, as well as the gas piping, be kept to a minimum.

(*a*) *Layout*

The piping should be carefully arranged to eliminate all unnecessary bends and fittings and should be as simple and as compact as possible. The layout should allow all elements of the system to be accessible for inspection and servicing. All pipes should have ample slope to drain all moisture condensed from the gas to low points, where manually operated drip traps should be provided to allow the removal of this condensate. Provision should be made for observing and keeping a check on gas pressures at critical points in the system. Thereby, the operator may easily determine the location and correct the cause of excessive pressure losses in the system.

(*b*) *Pressure losses—Size of piping*

Actual pressure losses, checked at plants which have been in service for some time, indicate considerable variance from pressure loss values computed by applying theoretical formulae. Losses have often been observed in excess of double the computed theoretical losses. It is quite probable that the sewage gas supersaturated with moisture and carrying particles of sludge and carbon in suspension, will form deposits in the gas lines. It has been noted from the operation records of various plants that during the starting up period the gas production may be 2 or 3 times the average expected production. The system must be designed to handle this condition which may last for quite an extended period of time. By providing for these peaks of gas production, while also taking into account the discrepancies between theoretical and observed values in losses, ample sized gas piping may be provided.

Where digester pressures of 5 in. to 6 in. are available, it is desirable to limit the losses between the digester and the point of use to about 1½ inches at the maximum gas flow. This will allow about ½ inch pressure differential for operation of the pressure relief to allow excess gas to pass to the waste-burner. The 1½ inch loss must include losses in gas lines, meters, flame traps, etc. It is desirable to provide the gas meters large enough to pass the maximum flow of gas with a pressure loss not to exceed ½ inch. The loss through the flame trap might also be limited to ½ inch. In most simple systems, the loss in the gas piping will be the only additional factor to be considered. This piping should be of ample size so that the loss in the piping system will not exceed ½ inch.

In gas systems where special equipment is required, such as gas scrubbers for hydrogen sulphide removal, excessive losses may require pressures in excess of that available at the digester. Fan type boosters can be placed in the system which will economically provide for any increase in pressure required. If this type booster is used it should be preceded by a pressure regulator to prevent the booster drawing a vacuum in the supply line, and bringing in air from the vacuum relief at the gas collector, when the rate of gas production is less than the capacity of the booster. The booster should also be provided with a mercoid shut-off switch to stop the booster when the pressure in the supply line drops to about 1 inch water column.

Storage of Gas

With the rapid increase in the number of uses for sludge gas, emphasis is now being placed on a more complete utilization of all gas produced. It may sometimes be found economically feasible to provide gas storage to secure a more complete use of this gas, but it must not be overlooked that the collection and storage of a large volume of inflammable and potentially explosive gas will add to the hazards in the gas utilization system. With a large volume of gas constantly available it is imperative that all protective and automatic shut-off devices and other controls are at all times functioning properly, also the possibility of securing an explosive mixture in a gas holder makes the selection of the proper type storage unit and controls very important.

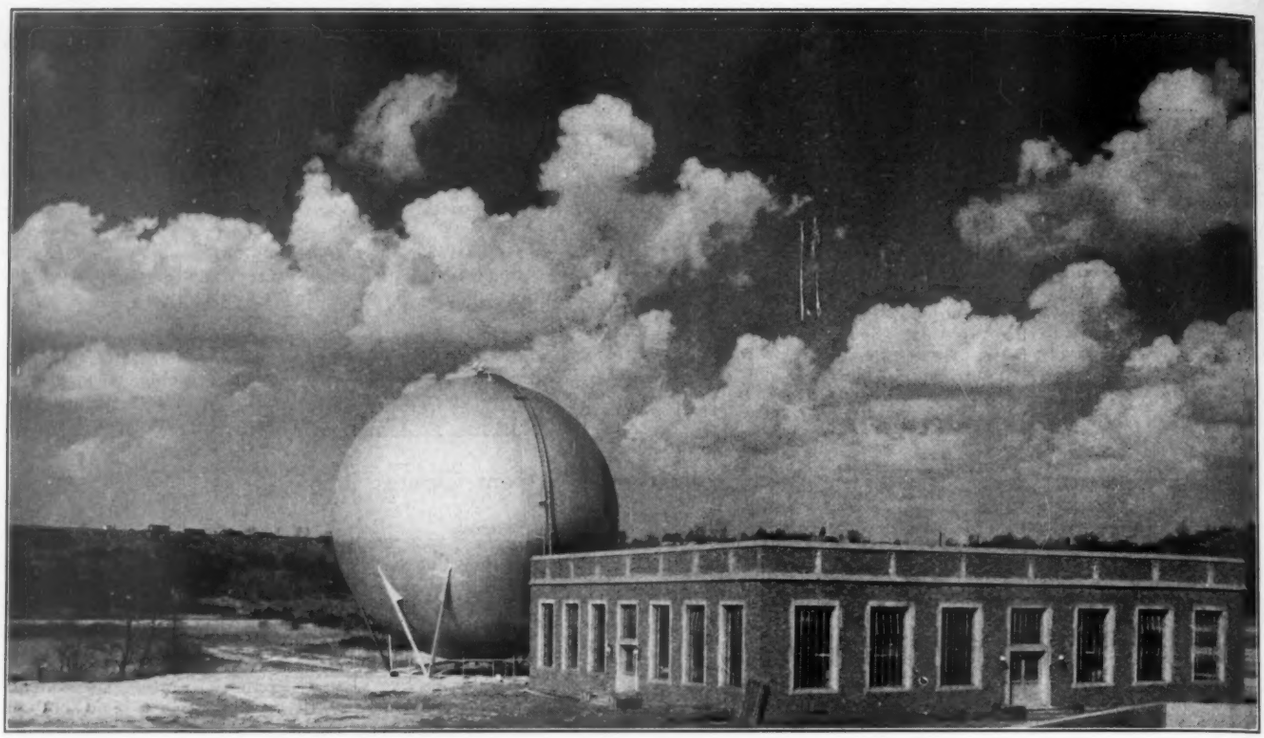
(*a*) *Types of Gas Storage Holders*

There are two main types of gas storage holders now in successful use in connection with the storage of gas at sewage treatment plants—the gravity storage holder and the pressure storage holder. The gravity type unit usually consists of a full volume lift in liquid seal tank. The installation at Greensboro, N. C., is of this type. There are, however, several successful installations of the piston type of gravity holder, this unit consisting of a movable piston in a steel holder tank provided with a mechanical sealing joint between the piston and the tank shell. This type of unit is generally used for storing very large volumes of gas.

The gravity type holder, whether of the piston or full volume lift, has the advantage of producing a uniform pressure over the entire range of effective capacity, but this pressure is dependent upon the weight of the moving element and in most cases is limited to a maximum of from 5 inches to 9 inches of water column. Pressure type holders operating at pressures up to about 50 pounds per square inch, provide the effective capacity by compressing the gas to ⅛ to ¼ its normal volume, and consequently for the same effective storage will take considerably less space. The pressure type unit will generally be more economical except in the smaller sizes, where the cost of the auxiliaries, which include compressors, automatic controls, pressure reducing and regulating valves, etc., offset the saving due to reduced size of the holder. Pressure storage will increase somewhat the complexity of controls, but they do provide practically an unlimited pressure which may be desirable in some cases, particularly in connection with utilizing of the gas in an incinerator where it may be desirable to operate mixing burners at pressures of from 2 to 10 pounds per square inch. Pressure holders are available either in cylindrical or spherical shaped units. The cylindrical or "bullet" holders are generally most economical for capacities up to about 15,000 cubic feet and for larger units the spherical holders will be found more economical.

(*b*) *Storage Requirements*

Regardless of the type of storage, controls may be provided so that only the gas which is produced in excess of the rate at which it is being consumed need be stored. By operating in this manner, the cost of compressing the gas for pressure storage will not be a major consideration. Automatic controls will allow excess gas to go to storage during periods when the production exceeds the consumption and to automatically bleed gas into the system when the consumption exceeds the production. By effectively scheduling the additions of solids to the digesters and maintenance of the proper digester temperature a fairly



Spherical Pressure Type Gas Holder—Southerly Plant, Cleveland, Ohio

uniform rate of gas production may be maintained so that where a normal steady use is contemplated, little or no gas storage may be necessary. For example, if gas is to be used solely for heating purposes by consumption in a gas fired boiler, the boiler will provide sufficient flexibility to burn all of the gas at the variations in rate of production which may be expected.

Where gas engines are provided, or where other uses are contemplated, the relationship of gas consumption to the expected production constitutes the critical factor in determining the quantity of gas storage necessary. If gas engine capacity is provided to consume the entire day's expected production in 8 hours, to eliminate peak power demand charges, it will be necessary to provide more storage than for an engine approximately one-third of the size which will be designed to operate continuously. The Tallman's Island plant of New York City with essentially no gas storage operates some 3,580 connected horse power of gas engines to drive blowers and pumps, providing all but a small fraction of the total power required to operate the complete activated sludge plant, including pumping of all sewage.* A study of the requirements for utilizing the sewage gas at the Westerly Plant at Cleveland, Ohio, for operation of an incinerator, indicated that 90 per cent of the annual gas production could be utilized by providing gas storage capacity equivalent to about 8 hours average production. On the other hand, for 100 per cent utilization a gas storage capacity equivalent to about 48 hours average production would be necessary. It was deemed economically feasible to provide only storage equivalent to 8 hours normal production, which would allow for the utilization of 90 per cent of the annual production. From these examples it may be seen that each plant design presents a separate problem and the amount of storage will be an economic study to be considered in the light of the individual conditions.

The most hazardous condition resulting from the use of gas holders develops when the holder is first put into service. As previously indicated, sewage gas presents an explosive hazard only when mixed with air. All gas holders should be completely purged before placing in operation by replacing the air with an inert gas such as carbon dioxide or nitrogen before adding sewage gas. This will eliminate the hazards of the explosive air and gas mixture.

Operation

It is impossible to design any system for the utilization of sludge gas which will be *completely* foolproof. Consequently, it is important that the operator realize the hazards which may be present and exercise ample care in operation. The operator must have a full knowledge of each device in the system and its function and relationship to the operation of all other units. A large scale diagram of the entire gas utilization system showing each device such as flame trap, drip trap, boiler controls, etc., together with pertinent notes indicating the function and the required attention for each device, will help the operator to become acquainted with the problems involved in his particular plant. A diagram of this type, similar to that here shown, if posted in a conspicuous and convenient place, will be a constant reminder to the operator of the importance of the proper function of each unit for safe operation. Operating and maintenance instructions for each device may well be posted adjacent to each individual piece of equipment.

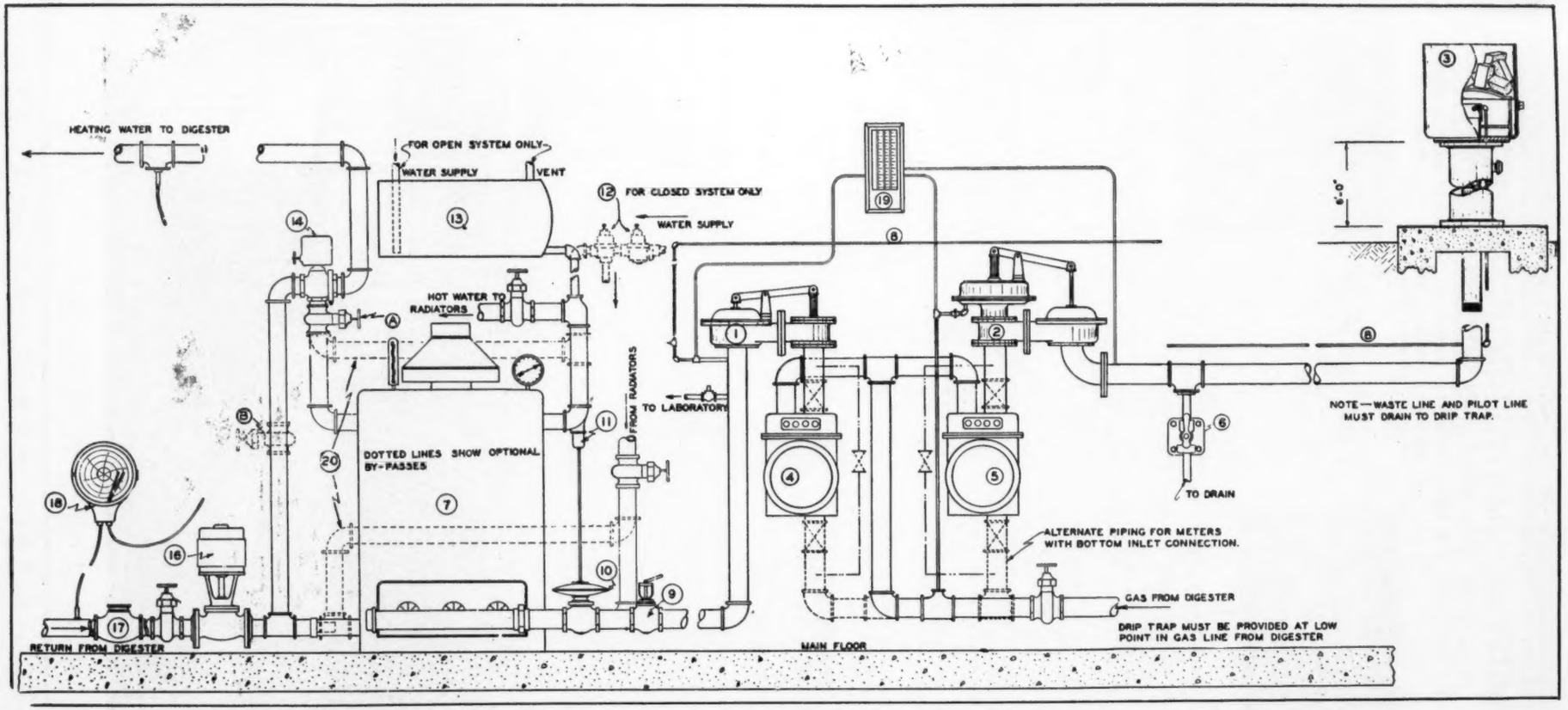
One of the most troublesome problems in the operation of a gas system is the removal of moisture condensate which collects in the gas lines. Drip traps are provided to allow the removal of this water at all low points in the system, but excessive moisture will sometimes collect in gas meters and other units. Provision should be made at critical points on the system for checking the gas pressures. By periodically checking the gas pressures at these critical points, the operator can readily determine the losses through the various units and note at a glance whether there is any restriction to the flow of gas. An excessive pressure loss through the gas meter or flame trap will indicate trouble at this point and the unit should be completely checked. The collection of moisture or possible clogging with some of the impurities from the gas will generally be the cause of excessive losses. All protective devices should be periodically checked to assure their proper operation. Flame trap elements should be inspected to be certain that they are not becoming clogged or corroded. The valve shut-offs on flame traps, the high temperature thermal shut-off and the thermo-pilot shut-off on the boiler, the low-pressure cut-offs and pressure reliefs, should be periodically operated to make sure that they are in operable condition.

With a properly designed system the operator's work may be simplified, but no matter how careful the designer may be, there is always a hazard present in any sewage gas utilization system and only by intelligent operation and proper care and maintenance can any gas utilization system be safely operated.

Summary

To summarize the subject of the design of gas utilization systems and the elimination of gas hazards, the following points should be borne in mind by the designing engineer and the plant operator:

*It must be said, however, that the Tallman's Island plant is not without the equivalent of a storage tank. This, inasmuch as the plant system is inter-connected with the system of the local gas company, which automatically comes into use if and when required.


HEATING WATER TO DIGESTER
FOR OPEN SYSTEM ONLY
WATER SUPPLY
VENT
FOR CLOSED SYSTEM ONLY
WATER SUPPLY
HOT WATER TO RADIATORS
FROM RADIATORS
TO LABORATORY
DOTTED LINES SHOW OPTIONAL BY-PASSES
TO DRAIN
ALTERNATE PIPING FOR METERS WITH BOTTOM INLET CONNECTION.
GAS FROM DIGESTER
DRIP TRAP MUST BE PROVIDED AT LOW POINT IN GAS LINE FROM DIGESTER
NOTE—WASTE LINE AND PILOT LINE MUST DRAIN TO DRIP TRAP.
RETURN FROM DIGESTER
MAIN FLOOR
6'-0"

Diagrammatic Layout of Gas System

Instruction for Operation, Inspection and Maintenance

(1) *Flame Trap—Check every six months (Oct. 1st-May 1st) operation of shut-off valve, and check every six months (Oct. 1st-May 1st) flame trap element, clean or replace if necessary.*

(2) *Pressure Relief and Waste Gas Flame Trap—Inspect every six months (Oct. 1st-May 1st) diaphragm of pressure relief.*

(4 & 5) *Gas Meters—Record reading 8:00 A. M. daily.*

(6) *Drip Traps—Remove moisture 8:00 A. M. and 6 P. M. daily.*

(7) *Boilers—Check thermo-pilot and shut-off valve operation weekly (Monday).*

(11) *Boiler Shut-Off—Check thermostatically controlled boiler shut-off weekly (Monday).*

(19) *Pressures—Check pressures in system daily at 8:00 A. M.*

(1) Gas systems should be kept under positive pressure at all times to eliminate air and gas mixtures entering the digestion tank, gas storage holder or gas piping system.

(2) Sources of ignition should be eliminated insofar as possible:

(a) Explosion proof motors and switches should be used in all buildings and control chambers where gas-air mixtures may be present.

(b) Open flames of no type should be allowed in the vicinity of tanks producing or storing gas. Warning signs such as "Danger—Explosive Gas," "No Smoking," should be conspicuously posted.

(c) Tools used in the vicinity of digestion tanks or gas storage tanks should be of a non-sparking nature.

(3) Unattended visitors should not be allowed around sewage treatment plants, especially in the vicinity of units producing or storing gas.

(4) Tanks recently emptied or being emptied should not be entered unless completely purged of gas and properly ventilated while an operator is working in the tank.

(5) Water seal traps or other water seal devices should not be allowed in a gas system.

(6) Flame traps of tried and proven design should be used rather than "home-made" devices.

(7) Flame traps should be placed adjacent to points of burning of gas, it being desirable to use an individual flame trap at each major point of gas use.

(8) All control chambers containing gas lines or appurtenances should be ventilated by means of a forced draft fan.

(9) All control chambers should be provided with ground level entrances.

(a) Portions of chambers not accessible by ground level entrance should be provided with convenient type stairway and designed so as not to require entrance of the operator during normal operation.

(b) Valve stems for valves located in inaccessible chambers should be extended to section of chamber which is easily accessible.

(c) Where operators find it necessary to enter inaccessible chambers for purpose of making repairs, etc., or find it necessary to enter dewatered digestion tanks, this should not be done unless another operator is on the outside and has access to a gas mask and other rescue means.

(d) Gas fired boilers should not be located in inaccessible chambers and proper stack ventilation should be provided.

(10) Safety equipment, consisting of gas mask and fire extinguisher, should be provided adjacent to points of danger.

(a) It is also desirable to provide suitable instruments for detecting explosive and toxic gases in control chambers.

(b) A telephone should be provided at each treatment plant for use in summoning aid in case of fire, explosion, etc.

(11) Gas appurtenances should be housed in a room separated from other portions of a control chamber or building. This room should be ventilated with its own ventilation system and have a separate entrance from the outside.

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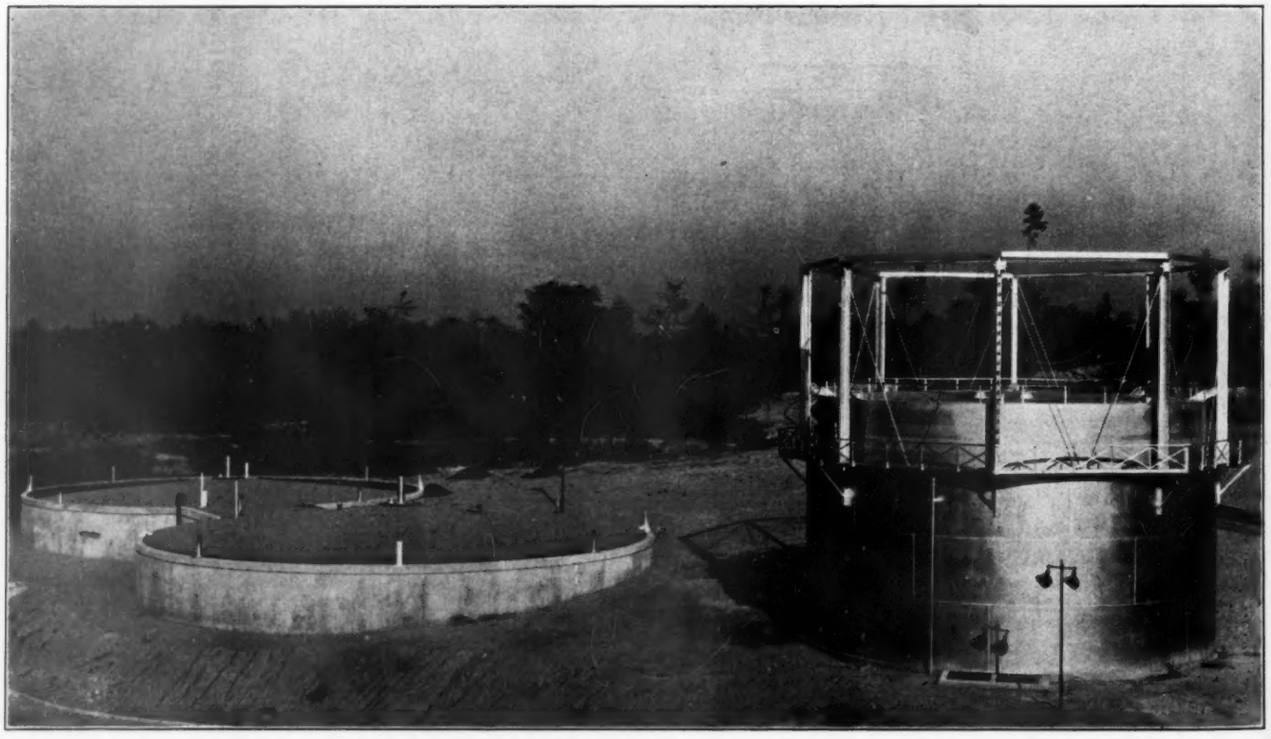

Gravity Lift Type Gas Holder—Greensboro, N. C.

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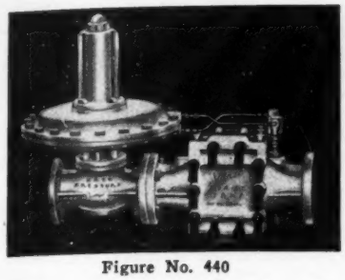


Figure No. 440

Sizes	2″	2½″	3″	4″	6″
Sh. wt...	125	140	160	200	260

←THE NEW "VAREC" *Approved* PRESSURE RELIEF AND FLAME TRAP ASSEMBLY

Unit consists of Diaphragm-operated Regulator, Flame Trap, and Thermal Shutoff Valve. Maintains a predetermined back pressure, passing surplus gas to Burner. Stops flame propagation. Patented telescopic flame trap element simplifies inspection and maintenance. Listed by the Underwriters' Laboratories for vent lines in oil tanks.

Figure No. 58C

"VAREC" *Approved* PRESSURE RELIEF AND VACUUM BREAKER VALVE WITH ← FLAME ARRESTER

Installed on digesters and gas holder domes, it affords emergency Pressure and Vacuum Relief and prevents flame entrance from atmospheric disturbances. Equipped with telescopic Flame Arresting element for easy inspection and maintenance. Pure aluminum. Non-corrosive. Listed by the Underwriters' Laboratories for Vent Lines in oil tanks. Sizes 2″ to 10″.

Sizes	2″	3″	4″	6″
Sh. wt.	70	105	160	225

"VAREC" *Approved* WASTE GAS BURNERS →

Installed wherever disposal of surplus gas is a problem. Unit has adjustable air intake in the venturi tube, pilot valve adjustable from outside. Long, Heavy cast iron draft stack insures proper draft and complete combustion.

Sizes	2″	3″	4″
Sh. wt.	450	480	500

Figure No. 236

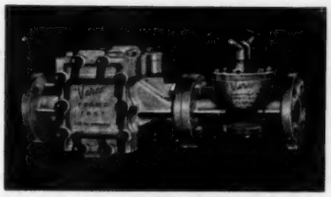


Figure No. 450

"VAREC" *Approved* FLAME TRAP ASSEMBLY

Flame Trap and Thermal Shutoff Valve. Unit self-contained, simple, foolproof. Installed in all gas lines supplying gas utilization equipment. No expensive fitting-up necessary. Arrests flame propagation. Easy inspection and maintenance. Aluminum and stainless steel. Non-corrosive. Flame Trap Element listed by Underwriters' Laboratories for vent lines in oil tanks.

Sizes	2″	2½″	3″	4″	6″
Sh. wt....	90	100	115	150	200

Figure No. 220A

"VAREC" *Approved* MANHOLE COVERS

Installed on digester and gas holder domes, affords quick and easy access. Has square, graphite-impregnated, fire proof gasket. Nonsparking. Gastight.

Sizes	18″	20″
Sh. wt.	100	110

Figure No. 51A

"VAREC" *Approved* FLAME CHECK

Acid resisting. Union type fitting. Positive flame stop for small lines. Has five 40-mesh fire screens. Easy inspection and maintenance.

Sizes	½″	¾″	1″
Sh. wt.	10	10	10

Figure No. 216A

"VAREC" *Approved* MANOMETERS

Single or Triple tube. Open or push-button control types. Accurate. Aluminum housing. Bronze fittings. Pyrex glass. Automatic—Fireproof—Safe. Sizes 6″ to 36″.

Sizes	9″	12″	15″
Sh. wt.	16	18	20

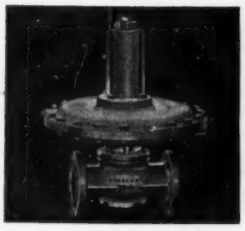


Figure No. 387

"VAREC" *Approved* SENSITIVE PRESSURE (REDUCING) REGULATOR SINGLE PORT

Maintains upstream or downstream pressure to within 0.5″ of water of predetermined pressure. Positive Shutoff. Aluminum body. Throttling type inner valve. 18-8 stainless steel trim. Sizes 2″ to 6″.

Sizes	2″	2½″	3″	4″
Sh. wt.	100	115	140	175

Figure No. 211A

"VAREC" *Approved* BACK PRESSURE (REDUCING) CHECK VALVE

Installed in relatively low pressure gas lines. Prevents back-flow through meters. Non-chattering, non-pulsating, non-corrosive, non-sparking.

2″	3″	4″	6″
20	35	70	125

Figure No. 187

"VAREC" *Approved* SUPER SENSITIVE PRESSURE (REDUCING) REGULATOR DOUBLE PORT

Maintains upstream or downstream pressure to within 0.2″ of water of predetermined pressure. Standard working parts 18-8 stainless steel with synthetic rubber diaphragm. Non-corrosive. Sizes ½″ to 10″.

2″	2½″	3″	4″	6″
190	200	233	260	350

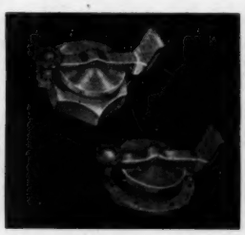


Figure Nos. 48 and 42A

"VAREC" *Approved* SAMPLING HATCH COVERS.

For use on digester domes. Available in several combinations of materials. Non-corrosive, gastight, self-closing, sparkproof. Figure 42A Flanged and Figure 48 Screwed.

4″	6″	8″	10″
12	17	23	27

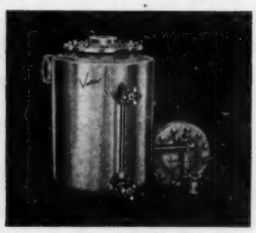


Figure No. 232D

"VAREC" *Approved* SEDIMENT TRAP AND CONDENSATE DRIP TRAP ASSEMBLY

Cast iron construction. 18-8 stainless steel working parts. Hand operated or automatic. Sizes 2″-2½″-3″-4″.

SEND FOR THE NEW "VAREC" SEWAGE CATALOG S-3 NOW

OPERATING ENGINES ON SEWAGE SLUDGE GAS*

Some Comments on Their Care and Operation

By THOMAS BROWN and GEORGE PRESTON

METHODS of sewage treatment, in which sludge is digested, made possible the production and connection of power producing gas from digesting sludge. In the earlier period of digestion of sewage sludge, the gas generated in the process was considered of no value, and it was burned to waste to prevent obnoxious odors. Then economy demands directed engineers to utilize the sludge gas in heating the sludge in the digestion tanks so as to maintain the required uniform digestion temperature, thereby improving the process of sludge digestion and the quality of digested sludge. In the past few years sludge gas has been put to use also in the generation of power by passing it from the digestion tanks through gas engines—these gas engines driving electric generators or air blowers or raw sewage pumps. To effect further utilization of the heat contained in the sludge gas, the jacket cooling water of the gas engines is passed through heat evchangers which heat the water circulated through the heating coils of the digestion tanks and building spaces. Additional heat is being recovered from the sludge gas by passing the engine exhaust through waste gas boilers to add additional thermal units to the hot water in the heat exchanger.

The Power in Sewage Sludge Gas

Gas from digesting sewage sludge is an excellent fuel for gas engines. It has an average heat value of 600 British thermal units per cubic foot, and values up to 650 or more units are obtained. Its composition is given in general as 64 per cent methane, 30 per cent carbon dioxide, 5 per cent nitrogen, a trace of hydrogen sulphide, and 1 per cent other gases .The gas is produced in a fairly uniform volume at all times in the normal operation of a sewage treatment plant; and possible peak flows or excess quantities may be stored in gas holders.

Generally a municipal sewage treatment plant of proper design can produce one cubic foot of gas per person in 24 hours; but an average conservative figure is three-fifths of a cubic foot. Supposing a sewage treatment plant serves a city of 100,000 people, and the average value of the sludge gas generated is 600 British thermal units per cubic foot, and assuming that three-fifths of a cubic foot of gas is generated per person per day, then the brake horsepower developed is: $(100{,}000 \times 3/5 \times 600)$ $(24 \times 10{,}000)$ or 150 horsepower. If one cubic foot of gas is generated per person per day, the horsepower generated would be 250 for a population of 100,000. If garbage is ground into the sewage, the gas production might be doubled, giving a power production of 500 horsepower per 100,000 population, or 5 per 1,000.

Scrubbing Sludge Gas

If the sludge gas contains an excessive quantity of H_2S or hydrogen sulphide, the pistons and cylinder walls of the engine are likely to be harmed; for the products of combustion, namely, the water and sulphur dioxide (SO_2), unite to form the very corrosive sulphurous acid (H_2SO_3); but any amounts of volatile sulphide are just as objectionable in the engine fuel as is hydrogen sulphide.

If the content of sulphide in sludge gas should exceed 0.07 per cent by volume, or about 50 grains in 100 cubic feet of gas, a gas scrubber should be placed ahead of the gas engine. The sulphur in the state of hydrogen sulphide is removed in the scrubber by passing the sludge gas through a bed of finely divided iron oxide held in wood shavings. The iron oxide reacts with the hydrogen sulphide to form water and sulphide of iron in accordance with the equation $Fe_2O_3 + 3H_2S = Fe_2S_3 + 3H_2O$. The wood shavings serve only as a sponge for the iron, keeping open the mass of iron oxide, so the gas can pass through the scrubber with a minimum of resistance. In order to promote the chemical action between hydrogen sulphide and iron oxide, the temperature of the gas scrubber should be kept above 60 degrees Fahr. Artificial heat may have to be supplied.

The gas scrubber may be built readily by the operating staff of the sewage treatment plant. If 160,000 cubic feet of gas is to be scrubbed per day, containing about 100 grains of hydrogen sulphide in 100 cubic feet of gas, the scrubber should be figured on the following basis: Enough iron sponge should be provided to last about 60 days. There is about 20 pounds of ferric iron in one cubic foot of sponge. Theoretically, 20 pounds or one cubic foot of ferric iron sponge will react with 127,000 grains of hydrogen sulphide. In actual operation, this reaction capacity will be cut to about one-third, or to 40,000 grains of hydrogen sulphide. Figuring 100 grains of hydrogen sulphide in 100 cubic feet of gas, and 160,000 cubic feet of gas per day, the total hydrogen sulphide to be removed in 60 days is 9,600,000 grains. Therefore the amount of iron sponge required is 240 cubic feet. The gas scrubber tanks should be large enough to hold this amount of iron sponge, and in addition there should be at least three inches of space at the bottom of the scrubber, underneath a tray, this space aiding in better distribution of the incoming gas to the sponge bed. The scrubber should be coated inside with a bituminous paint.

The iron sponge can be used over again after regeneration. When it has become exhausted or sulphided in the 60-day period, it is exposed carefully to the air so as to allow the iron sulphide to absorb oxygen, enabling the iron to revert back to its original ferric oxide state according to the equation $2Fe_2S_3 + 3O_2 = 2Fe_2O_3 + 6S$. There is so much heat generated in this reaction that there is danger of the iron sponge starting to burn and be destroyed. The rate of heat generation can be controlled by wetting the exhausted iron sponge thoroughly with water, taking it then from the scrubber tank and piling it in the open air. After the sponge has charged from blacw to brown in color, it can be placed back in the scrubber; it should be placed uniformly and tamped lightly as it is placed to fill all space evenly. The iron sponge can be regenerated two or three times in this manner, before it has to be discarded finally.

Engines for Sludge Gas

Gas engines for running on sludge gas are built generally in sizes from 15 to 1,800 horsepower. They are connected direct to electric generators, or to air blowers, or to sewage pumps by way of gearing, or to other mechanical equipment. They are used full or part time, all or part of the installation, as gas becomes available. For running a gas engine full load and full time in spite of insufficient sludge gas supply, city gas can be made available for standby.

The heavy duty slow speed gas engine is preferred to other gas engines. It can run for several years continuously with low cost of maintenance and repairs. In the smaller size of gas engine the valve-in-head type is preferred. By installing a carburetor, gasoline may be used as fuel instead of gas. The gas engine can be expected to have a normal life of 20 years. Repairs will run about $2.00 per year per brake horsepower. The gas engine is required to run almost continually, for if it is shut down, generally considerable electric power must be purchased and a high kilovolt-ampere demand results.

The sludge gas enters the engine by way of a gas mixing valve in which the gas is mixed with atmospheric air in proper proportion. The valve has a function which is similar to that of the carburetor used in gasoline engines, and it contains an air valve and a gas valve, each regulated separately; due to this arrangement the fuel mixture can be changed to suit the changing British thermal unit content of the gas. Just ahead of the gas mixing valve, the gas pressure is reduced to atmospheric pressure by use of a suitable pressure regulator. By installing a gas reservoir between the pressure regulator and the mixing valve, the operator can maintain a constant supply of gas at the atmospheric pressure; and this reservoir should be at least 30 cubic inches in size per horsepower of engine rating.

Generally speaking, at full load the fuel consumption of the gas engine does not exceed 10,000 British thermal units per brake horsepower-hour, which equals 15,000 British thermal units per kilowatt hour. If the sludge gas has a low heat value of 575 British thermal units per cubic foot, a kilowatt-hour generated requires 26.1 cubic feet of gas at full load, 27.5 at 5/6th load, 29.3 at ⅔rd load, and 32.7 at ½ load.

Installations of Gas Engines

Hundreds of installations of gas engines running on sewage sludge gas have been made during the last few years, including

*This article, from *The International Engineer* of May, 1941, so well tells the story of power generation from sludge digestion gas, that we have asked permission to reproduce it.—Ed.

at least 3,500 horsepower at Tallmans Island plant, New York City; 1,820 at the Coney Island plant, New York City; 835 at Peoria, Ill.; 360 at Detroit, Mich.; 300 at Cedar Rapids, Iowa. [See appended list of engine installations. The largest will be that at New York's Jamaica plant, with 3 engines of 1,440 H.P. each—i. e., 4,320 total H.P.—Ed.]

Gas and Air System.—The fuel gas system of the engine consists as a rule of a gas holder or reservoir (which may be a floating cover on the digester tank), a gas meter, a pressure regulator, a mixing valve, and a governor. The governor needs careful attention; its rotating parts must be kept lubricated properly—when the lubricating oil is discharged back to the crank case, attention must be given that the blowby gases are not depositing water in the governor. Keep all flat wearing surfaces of the governor free of depressions so that it continues to respond smoothly and rapidly. Inspect the governor every time the piston is removed.

Draw all intake air through adequate filters; for dust drawn into the engine with the air accelerates the wear of moving parts. All intake air lines should be large which prevents high losses in pressure when the engine is running at full load. The mixiing valves need adjustment and lubrication occasionally. Water should be kept out of the gas piping.

Air Starting and Safety Devices

The air starting system of the gas engine includes air compressor, air reservoir tanks, and air piping. The air compressor should be inspected occasionally and repaired if necessary. See that the condensate drains properly from the air starting tanks and piping. Check blow-off cocks, and float-operated condensate separators on the tanks, periodically to be sure they remove water from the air storage tanks and air lines, and prevent the fouling of spark plugs due to injection of water into the engine cylinder.

The ignition system consists of magnetos, or battery-operated spark coils, timed distributors, high tension distribution wiring and spark plugs. Keep the voltage generated at a minimum to keep the magneto or spark coil in best operating condition; do this by keeping the spark gaps at or near the minimum for production of a good spark. Change or clean spark plugs and re-adjust the gap when the gap increases from the normal 0.025-inch setting to about 0.050 inch. The double electrode plugs are well suited to the gas engine. Spark plug gap adjustment may be required once a month. Clean magneto and distributors once each year and adjust or replace electrodes as needed. Check timing settings against the flywheel markings every time the timing mechanism is dismantled. Inspect high tension wiring for cracks and take precautions against possible cross firing where wires are adjacent to each other.

The engine protective devices generally are instruments actuated by pressure, temperature or mechanical movements, thereby operating electrical switches or relays. These relays and switches ground the magnetos and close the fuel gas valve, so that the engine is shut down. If the gas engine drives an electric generator, there is also a generator breaker which is tripped and the electrical system cleared for normal operation.

Pressure gauges, tachometers, pyrometers and other indicating devices should be kept in good operating condition. All delicate indicating devices and safety devices, and all gauges should be kept mounted on panels which are isolated from the engine so they will not wear due to vibration. The safety devices and gauges should be inspected and checked quite often to make sure they operate properly. Check the protective devices which shut the engine down when the temperature becomes excessive or when the pressure of cooling water or lubricating oil should drop below normal. Also check the overspeed protection device.

Maintenance Schedule

Following a routine maintenance schedule will insure the operation of the gas engine with a minimum of shutdowns. Details of maintenance on the gas engine are affected by the size, speed, operating condition and design of the unit. The operating engineer should have a routine maintenance schedule for each engine to follow throughout the year. He should keep a complete record of all maintenance work on the unit. Such records will help to work out a more reliable maintenance schedule and overhauling schedule as the years pass; and it enables the engineer to keep a closer check on the performance of each engine part. Dated records should be kept on crankshaft allignment, clearance of piston rings, bearing clearance. The operating engineer should take note also of the condition of piston rings, pistons, liners, oil conditions, dimensions and replacements of piston rings, diameters of liners, etc.

Main Crankshaft and Connecting Rod Bearings

After the gas engine has been run for some time, the main crankshaft and connecting rod bearings should be inspected at the rate of once per year. The bearings should be checked for clearance. The main crankshaft bearings must be checked for proper alignment; this should be done after the main bearings are adjusted and whenever the pistons are removed. Any misalignment can be determined by measuring the deflection of the crankshaft flanges when rotating the shaft. Mount a sensitive deflection gauge between the parallel crank faces of the crankshaft and take readings at 90-degree intervals in the shaft rotation.

If the gas engine is run with misaligned main bearings, a repeated flexing of the crankshaft metal occurs and in the end there will be crystallization and failure of the shaft. If the measured deflection of a large gas engine is .003 inches, the bearings should be adjusted. The bearing adjustment can be done by removing and scraping the lower half of the main bearings until the proper alignment has been obtained. To estimate the clearance in bearings, the most satisfactory way is to remove the small shims, reassemble the bearing until it just binds in the shaft, and then reinsert the proper size of shim to provide the correct clearance.

Every two or three years the clearance between the wrist pin and wrist pin bushings should be measured. If there is a thump of pronounced intensity, it indicates that a wrist pin assembly has become defective. In this case press the pin out of the piston, and measure the diameter of both the pin and bushing with a micrometer gauge. If excessive wear has occurred, grind the pins to true circular section and install new bushings of correct diameter.

Cylinders and Pistons

About every six to eight months the piston should be removed from the gas engine so that carbon deposits can be removed from around the rings and so that any rings showing excessive wear can be replaced. Clean the piston and piston rings thoroughly of gumming oil and hard carbon. The oil holes back of the piston grooves should be cleaned. Replace the piston rings on the same piston from which they were removed. Stagger the ring gaps on opposite sides of the piston. Liner packing rings should be checked for tightness after the engine has been reassembled, by placing the water jacket under water pressure and watching for water leaks into the crankcase.

If pistons are operated for a prolonged time with piston rings stuck, the piston and liner may become scuffed or gouged. If there is an indication that the piston rings are not working properly, clean the piston and free the piston rings at the earliest hour possible. When excessive blowby of cylinder gases into the crankcase is noticed, or when there is a marked increase in the consumption of lubricating oil, it is likely that some of the piston rings have become stuck in the piston ring grooves. By removing the piston rings promptly and correcting the condition, excessive wear on pistons, piston rings and cylinder liners resulting from higher temperatures and poor lubrication is stopped or prevented.

When the piston is being cleaned, inspect the piston rings for wear and ring gap. After the piston rings have been placed on the piston, check the clearance between the rings and groove, by use of a feeler gauge. The seat for the piston ring should be square, and there should be no excessive taper in the ring groove, for this may lead to sticking of the rings. If power or compression rings are to be used over again, chamfer them slightly with a file to remove sharp wearing edges. The oil control rings of the scraper ring type should have a relatively small bearing area and also a sharp scraping edge.

It is best, after the head has been taken off and the liner and piston removed, to measure the diameter of the liner in both transverse and lateral direction at three points of the piston stroke. Then make a record of the readings and compute the amount and rate of wear. After a new engine has been run for some time, the average maximum increase in diameter of the liner may amount to from .0004 to .0005 inches in 1,000 hours of operation. Cylinder liners may stand three reborings, after which new ones should be installed. Any rings showing excessive ring gap, lack of tension and an undue reduction in radial thickness should *not* be used again.

Valves Need Checking

Whenever the engine is dismantled, check the air starting valves and the valve motion devices including gears, camshaft, cams, push rods, and valve operating rockers.

Reseat the exhaust and intake valves periodically to be sure

they will work properly. The exhaust valves should be reseated every two to three months, and the intake valves should be reseated every four to six months. If the valve discs and seats have become pitted, they should be placed in a lathe and ground with a carborundum wheel until all pitting is removed; or the pitting may be removed with a cutting wheel.

Small quantities of carbon and dust depositing between valve stems and guides may cause the valve to stick. This occurs most likely after the engine has been shut down. Clean the valve surfaces and inspect them for proper clearance. Excessive clearance of the valve stem will cause the valve to move sideways too much so that it may not close completely over the entire seat; and the valve disc may start to warp in reference to the stem. It is possible that the valve disc has warped already on the stem, and therefore will have to be aligned. If the valve guides have worn too much, cast iron bushings can be inserted to provide again a proper clearance. Hard steel bushing inserts may be obtained for the valve cages, and also replaceable valve seats.

In larger engines the valves should be in removable cages, or they should be installed in some other way which makes them easily removable for inspection and for grinding of valves. The operating staff should keep a stock of removable valve seat inserts.

If the valve does not seat properly, injury may result to the valve and the gas engine will lose power and operate unevenly. After the valves have again been assembled in their cages, the seating surface should be lapped in with a good grinding paste. Later the fit should be checked by using a colored paste, as for example prussian blue. First apply some prussian blue paste to the cage seat. Then wipe to a thin film with a dry cloth. Then place the valve in the cage. Then rotate the valve disc slightly. Then check the disc which should show a continuous ring of blue. If it does not, more grinding is necessary to make a true contact. Smaller valves may be ground completely more economically by the lapping method only.

Having replaced reground valves, the clearance between the valve stem cap and the valve operating mechanism should be adjusted properly. Inspect this clearance quite often for about two days after they have been put in service and adjust whenever necessary; for there may be a change in clearance for a day or two due to the hammering of the valve. It is a good plan to *inspect the valves about once a week* to make sure that a proper clearance is maintained.

Lubrication

Most careful attention should be given to the lubricating oil system consisting of engine sump or oil storage tank, oil pump, oil filter, or screen, oil cooler, oil centrifuge, or purifier, and oil distribution lines. The best quality of oil obtainable for the purpose should be used in the plant. After a new installation has been started, the oil should be checked say weekly for suspended solids, for viscosity, for water, for neutralization number, and also for sulphur content if the gas burned contains an appreciable amount of hydrogen sulphide. An oil changing and oil purification schedule should be worked out from experience to meet engine requirements; and once this has been done, the *oil conditions* may have to be *inspected only about once a month.*

When operating conditions are normal and a batch system of purifying the oil is used, the oil should be removed fully once a month and new or purified oil substituted. The oil tends to build up solids, due to thermal decomposition. Water which forms in the crankcase of the engine from blowby of combustion gases, leads to the forming of oil-water emulsions which are sometimes called sludge. When accumulating in the crankcase, this sludge should be removed completely before any new or purified oil is added to the system. The rate of oil decomposition and the formation of sludge being increased by excessive blowby of the combustion gases, oil inspection and oil changing may be required more frequently if excessive blowby occurs.

The operator should never allow the sludge to accumulate so it will be pumped through the oil circulating system. The oil pump for the main distribution system should be checked frequently to insure the correct discharge pressure. Oil screens installed to remove coarse particles should be cleaned every three or four months.

It is best to remove the water and sludge from the crankcase by using a gear pump with flexible suction hose. Do not wipe the crankcase with rags, for the lint left might be pumped through the oil lines and deposited on the screen, which will result in lower oil pressure in the system.

Oil Cooling and Purifying

The temperature of the oil in the cooler should not exceed 160 degrees Fahr., and water should not be allowed to leak into the oil. There should be thermometers in the oil line before and after the coolers. When the temperature differential for operating the cooler is not sufficient, the cooler should be bypassed and cleaned. The cooler should be cleaned periodically; remove the tube bundle and boil it in a 10 per cent solution of tri-sodium phosphate (which is an emulsifying agent) until the sludge settled in the tube bundle is removed and softened. Then blow the bundle out with compressed air to remove traces of softened material.

The oil in the circulating system should not contain more than 0.75 *per cent suspended solids.* The solids content can be reduced in a centrifuge to about 0.15 per cent, and the water content to less than 0.1 per cent moisture. For centrifuging, the oil should be heated first to 140 to 160 degrees Fahr., with a relatively low-temperature element. The oil heater should not be of the instantaneous type, for the element in this heater is so hot that there is danger of breaking down the oil causing carbon deposits around the heater, which insulates the heater and causes it eventually to burn out.

When the engine is dismantled, check the oil distribution lines. Check also the link mechanism of the force feed lubricator for wear and replace worn parts if any. Also check the lubricating pump for rate of discharge.

Waste Heat Equipment

The cooling water should be maintained soft enough to prevent calcium and magnesium salts from depositing on the surface of the water jackets. The engine cooling water jackets should be inspected periodically for scale deposits. If there are heavy deposits, correct the water conditions to prevent further deposits. Excessive deposits overheat engine parts as a result of lowering the heat transfer rate. It is preferable to use a closed system of water cooling; for in the open system using evaporation by cooling tower, deposits are built up. When a closed cooling system is used, the return water to the engines can be kept between 90 and 100 degrees Fahr. and the water discharged from the engine jackets should not exceed 160 degrees Fahr. Periodically check the water pumps, water jackets and cooling facilities of the cooling water system.

All or part of the waste heat from the engine jacket cooling water can be recovered for use in the water heating system of the building spaces and digestion tanks. This heat recovery saves coal or oil fuel which would otherwise be required to supply the heating system. In a four-cycle slow-speed gas engine of about 90-horsepower capacity, for example, operating under full load, the heat content of gas fuel is applied as follows: 25 5 per cent in useful work, 3.5 per cent in radiation, 33.5 per cent in jacket cooling water, 37.5 per cent in exhaust and friction. Practically all of the 33.5 per cent of heat going to the jacket cooling water can be recovered in a hot water heating system.

It is recommended to *have the cooling water enter the engine jacket at between* 110 *and* 130 *degrees Fahr. and have it leave the engine at between* 140 *and* 160 *degrees Fahr.* To effect efficient cooling of the engine, about 3,300 British thermal units must be removed from the engine jacket water per brake horsepower per hour. In passing the engine jacket water through the heating coils of the digester, therefore, this amount of heat must be extracted from them both winter and summer; if not all of this amount of heat can be extracted from the so-called water cooler in the digester, (that is, the digester heating system), part of the jacket water has to be circulated through a separate water cooler, as for example during the summer season, to obtain the required cooling effect.

The heat that can be removed from the jacket water of a 90-horsepower engine under full load is 297,000 British thermal units per hour. For a 30-degree Fahr. temperature rise the amount of jacket cooling water required is 1,190 gallons per hour. Cooling of the water is effected in the digester heating system or in some other way, and a circulating pump of at least 1,190-gallons-per-hour capacity is needed to effect positive circulation of water. There should be a vented surge tank at the high point of the jacket water system, placed just ahead of the circulating pump or between the engine outlet and the cooler. There should be a thermometer at the cold water inlet and at the hot water outlet.

Waste Heat Boiler

In some gas engine installations the exhaust gases are exhausted to the atmosphere by way of exhaust silencers and waste heat boilers. If a waste heat boiler is used to extract enough heat from the exhaust gases to cool them from 900 degrees Fahr., to 300 degrees Fahr., and a high boiler water temperature is desired to guard against possible condensation and corrosion, the jacket cooling water of the engine may be pumped into the

boiler after preheated to 140 degrees Fahr. The waste heat boiler acts as a silencer for the engine, and if there is a by-pass around the waste gas boiler, it should have an exhaust silencer.

The waste heat boiler requires great care in operation. Water must not be permitted to condense on the gas side of the tubes if maintenance costs are to be kept low. Condensate forming on the gas side of the boiler tubes results in rapid corrosion and tube failure. When waste heat or exhaust gas boilers are not in use, they should be disconnected completely, for valves used in exhaust gas lines do not seat tightly and the gases filtering into the boiler corrode the gas side of the tubes due to deposit of condensate.

Condensation of water on the gas side of tubes, due to cold boilers, can be prevented by generating steam in the boiler and converting it to heating uses; or by heating water in the boiler and controlling its flow in such a manner that the temperature of the water will not drop below 180 degrees Fahr. At points where radiated heat will affect the operation of engine devices, the exhaust gas lines should be kept insulated. The heat radiated from the eingine, which is about 3.5 per cent, cannot be transferred to the hot water heating system; this radiation helps cut down the heating load by heating the engine room partially.

The dewpoint, or the temperature at which condensation on the cooling surfaces of the waste heat boiler begins, is about 130 degrees Fahr. As the gas contacts the boiler surface, there is a sudden drop in temperature; therefore the exhaust gases can be cooled only to that temperature where they will leave the boiler without condensation. *The inlet temperature of the boiler water should not be less than* 130 *degrees Fahr.; and a safe minimum temperature of the exhaust gas is* 300 *degrees Fahr.*

If feed water is not available at 130 degrees Fahr., the waste heat boiler may be used to generate low-pressure steam which is passed to an independent tubular heater, the condensate returning to the waste heat boiler generally well above 130 degrees Fahr. Excess sludge gas, that is not used in the gas engine, can be fired in a gas boiler to supplement the waste heat recovery boiler.

Exhaust gases from a 4-cycle gas engine having water-cooled exhaust manifold, have a temperature of 800 to 900 degrees Fahr.; and exhaust gases from a two-cycle gas engine have a temperature of 300 to 500 degrees Fahr. A 90-horsepower four-cycle engine will produce about 1,130 pounds of exhaust gas per hour at full load, from which at least 150,000 British thermal units can be recovered per hour.

SLUDGE GAS ENGINE INSTALLATIONS IN THE UNITED STATES**

Year	Location	No. of Units	Horse-power*	Driving
1926	Plainfield, New Jersey	2	15	Blower
1928	Charlotte, North Carolina	1	225	Blower
	Charlotte, North Carolina	1	75	Pump
1930	Rockville Centre, New York	1	30	Blower
	San Bernardino, California	1	40	Generator
1932	Rockville Centre, New York	1	60	Blower
	Springfield, Illinois	1	180	Blower
1934	Springfield, Illinois	1	157	Bl. & Gen.
1935	Los Angeles County, California	1	200	Pump
	Cedar Rapids, Iowa	1	210	Generator
	Palo Alto, California	1	40	Generator
	Ontario, California	1	40	Blower
	Madison, Wisconsin	1	230	Blower
	Ann Arbor, Michigan	1	120	Blower
	Peoria, Illinois	1	535	Blower
	Peoria, Illinois	1	300	Blower
	Durham, North Carolina	2	150	Generator
	Greencastle, Indiana	1	50	Blower
	Toledo, Ohio	1	300	Pump
	Toledo, Ohio	1	225	Generator
1936-7	New York City, New York—			
	Coney Island	3	300	Generator
	District of Columbia	1	1200	Generator
	Janesville, Wisconsin	1	30	Generator
	Topeka, Kansas	2	180	Blower
	Richmond, Indiana	1	120	Blower
	Edwardsville, Illinois	1	15	Generator
	Sheboygan, Michigan	2	120	Pump
	Green Bay, Wisconsin	1	120	Generator
	Green Bay, Wisconsin	1	90	Generator
	Fort Atkinson, Wisconsin	1	40	Generator
	LaCrosse, Wisconsin	2	90	Generator
	Hutchinson, Kansas	1	90	Generator
	Elmhurst, Illinois	1	30	Generator
	Kokomo, Indiana	1	45	Generator
	Kewanee, Illinois	1	30	Generator
	Wichita, Kansas	1	70	Pump
	Litchfield, Illinois	1	30	Generator
	Dixon, Illinois	1	30	Generator
	Chicago Heights, Illinois	1	125	Blower
	Atlanta, Georgia—			
	Intrenchment Creek	2	120	Generator
	Clayton	2	180	Generator
	Grand Rapids, Michigan	1	50	Generator
	Aurora, Illinois	2	70	Pump
	Madison, Wisconsin	1	230	Generator
	Monroe, Wisconsin	1	30	Generator
1938	New York, New York—			
	Tallmans Island	2	800	Blower
		2	450	Blower
		2	350	Pump
		2	150	Pump
	Columbus, Ohio	3	750	Generator
	Detroit, Michigan	1	364	Generator
	Fort Dodge, Iowa	1	275	Generator
	Lansing, Michigan	1	240	Blower
	Oshkosh, Wisconsin	2	160	Generator
	Albuquerque, New Mexico	1	150	Generator
	Findlay, Ohio	1	90	Blower
	Battle Creek, Michigan	1	50	Pump
	Newcastle, Indiana	1	45	Blower
	Crawfordsville, Indiana	1	44	Blower
	LaPorte, Indiana	1	27	Generator
	Greensboro, South Carolina	2	160	Generator
	Michigan City, Indiana	1	74	Generator
1939-40	Greenville, South Carolina	2	225	Generator
	Springfield, Missouri	2	198	Generator
	Rock Island, Illinois	5	125	Pump
	Rock Island, Illinois	2	75	Pump
	Rock Island, Illinois	1	75	Generator
	Cedar Rapids, Iowa	1	100	Pump
	Belleville, Illinois	1	100	Blower
	Sharon, Pennsylvania	2	80	Generator
	Butler, Pennsylvania	1	80	Generator
	Wausau, Wisconsin	1	75	Generator
	Wausau, Wisconsin	1	50	Generator
	Wausau, Wisconsin	1	50	Pump
	Pueblo, Colorado	3	75	Pump
	Manitowoc, Wisconsin	1	75	Pump
	Manitowoc, Wisconsin	1	35	Pump
	Davenport, Iowa	1	75	Generator
	Davenport, Iowa	1	75	Pump
	Kenosha, Wisconsin	2	75	Pump
	Stevens Point, Wisconsin	1	75	Generator
	Marion, Indiana	2	75	Blower
	Marion, Indiana	1	50	Pump
	Ithaca, New York	1	50	Pump
	Lake Charles, Louisiana	1	50	Blower
	Carlsbad, New Mexico	2	50	Pump
	Metairie, Louisiana	1	50	Blower
	Two Rivers, Wisconsin	1	43	Blower
	Two Rivers, Wisconsin	1	40	Pump
	Escanaba, Michigan	1	40	Generator
	Shawano, Wisconsin	1	35	Generator
	Litchfield, Illinois	1	30	Generator
	Monroe, Michigan	1	25	Pump
	Gary, Indiana	3	175	Pump
	Gary, Indiana	2	300	Blower
	Cleveland, Ohio	2	390	Blower
	Fort Wayne, Indiana	1	450	Blower
	Adrian, Michigan	1	45	Blower
	Peru, Indiana	1	45	Blower
	Pontiac, Michigan	1	150	Blower
	New York City, New York—			
	Jamaica[1]	3	1440	Generator
	Coney Island[1]	3	920	Generator

[1]Not yet installed. *H.P. of each unit. **(Compiled by Ralph E. Fuhrman, Ass't Supt., Sewage Treatment Works, Washington, D. C.)

CHICAGO PUMP COMPANY

2349 Wolfram St., CHICAGO, ILLINOIS

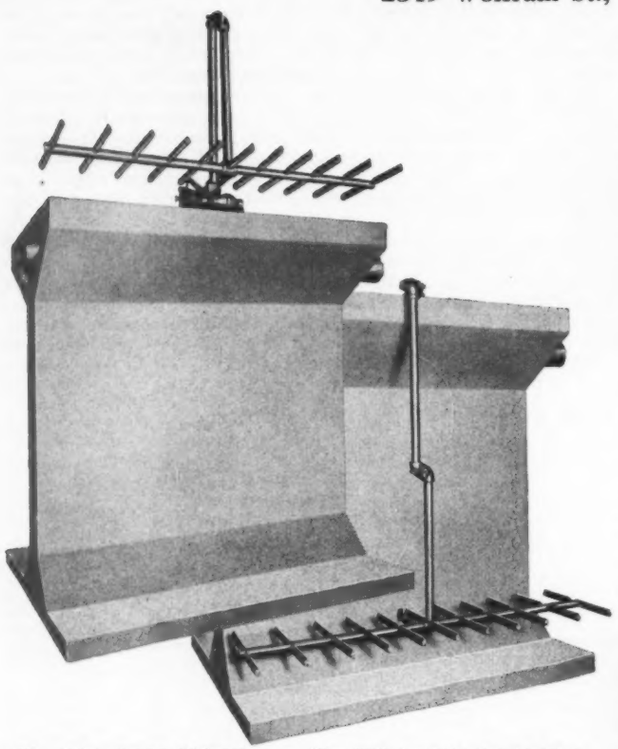


Fig. 2914—Swing Diffusers
Controlled aeration for the Activated Sludge Process. For towns of 4,000 and up. Diffuser tube assembly can be raised to tank walk. Simple regulation of air supply from tank walk. Tube cleaning without dewatering tanks or interrupting operation. Ask for Bulletin 175.

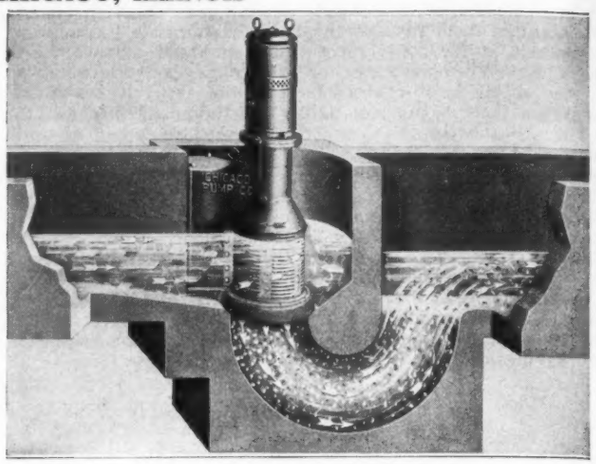


Fig. 2202—Comminutor
Eliminates screenings and screenings disposal—No burial; No incineration. Cuts coarse sewage matter into small settleable solids without removal from the channel.

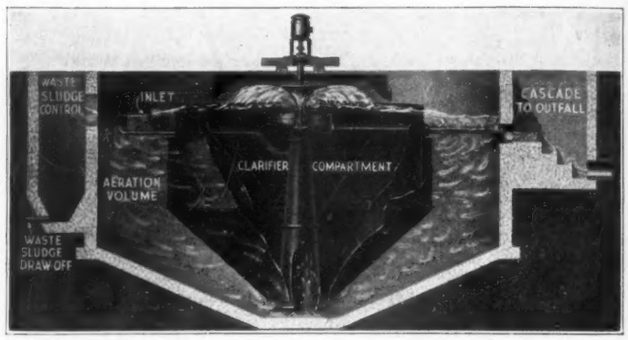


Fig. 2349 (right)**—Combination Aerator-Clarifier**
providing complete treatment of sewage without odor nuisance and with minimum manual operation. Ideal for housing projects, small camps, institutions and small towns. Over 75 units operating successfully. Ask for Bulletin 128-K.

Fig 2504—Vertical Open-Shaft Non-Clog Pump
Universal Flexible Couplings in shaft compensate for misalignment. Ask for Bulletin 126.

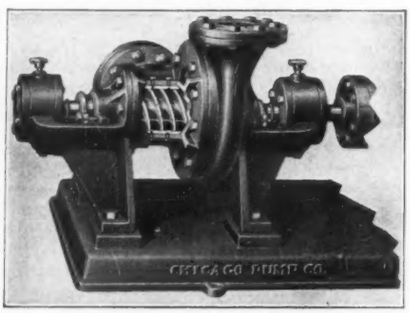


Fig. 1860—Scru-Peller Primary Sludge Pump
Screw conveyor in the suction ahead of the impeller. Stellited cutters prevent clogging. The capacity can be varied instantly. Ask for Bulletin 190.

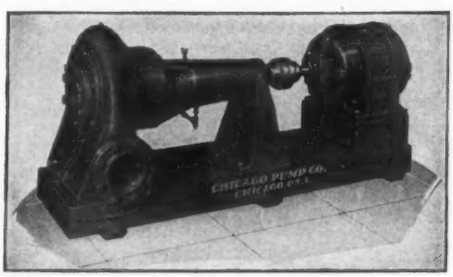


Fig. 1774—Horizontal Non-Clog Pump
Being mounted directly on base prevents pump being pulled out of alignment by long lines of piping. Ask for Bulletin 127.

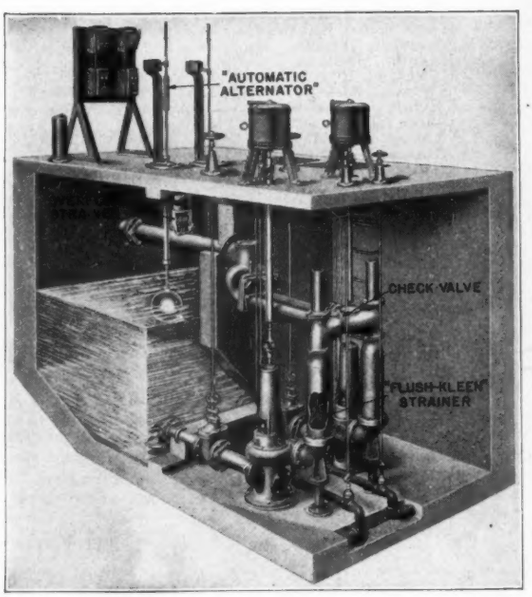


Fig. 2038—Flush-Kleen Sewage Pumping Station
Requires no attention. NEVER CLOGS. Automatically backwashes strainer. Keeps solids from basin and pumps. Impeller handles water only. Coarse sewage matter is stopped by Flush-Kleen strainer and is flushed out through discharge pipe. Check valve prevents discharging back through inlet line. Ask for Bulletin 122.

SLUDGE PUMPING

A Discussion on Pumps, Installation, Design and Operating Problems

By S. E. KAPPE, Engineer
Chicago Pump Co., Washington, D. C.

THE purpose of this paper is to discuss briefly the problems encountered in moving sewage sludges from one tank to another. The paper covers the type of pumps used for sludge pumping, their respective advantages and disadvantages, the design of sludge lines, and the problems involved in sludge pumping and their solution. Since the writer's firm manufactures all types of pumps commonly used for sludge pumping, an opportunity is presented to discuss the subject from experience gathered in actual plant operation.

The Plunger Pump

The plunger pump is popular because of its positive displacement characteristics. It will pump mixtures of sludges, sewage gases, and air equally as well as liquids. It is this self-priming feature which makes the pump more readily primed than a centrifugal pump where a suction lift is involved, or high spots exist in the suction line where gases may accumulate. Beyond this characteristic, however, it is questionable whether this pump offers any other superiority over other well-designed sludge pumps.

The following are some of the objectionable features of the plunger pump. The pump is often very noisy, complaint being frequent that it pounds and knocks. Such pounding is due to the reversal stresses in the different parts of the pump, caused by the starting and stopping of the column of heavy fluid on the suction and discharge side at each stroke. This noise can often be minimized by providing adequate air chambers on both the suction and discharge sides, and by reducing the pump speed. The reverse flow of the sludge through the valves is commonly known as slippage. It reduces the delivery of the pump, and, as a consequence, its efficiency.

Another objectionable feature is the maintenance required to keep the packing tight. If the packing is too soft, too loose, or improperly placed, the operator might find himself as well as the walls and floor sprayed with sludge, leaving an unpleasant taste and a messy cleaning job. Then if the packing is *too* tight, scored pistons or cylinders and broken shear pins may be experienced. The amount of grit in the sludge will govern the life of the packing and, likewise, the wear to which the pistons and cylinders will be subject. An effective grit chamber at the head of the treatment plant is an asset in prolonging the life of sludge pumps, and plunger type pumps in particular.

The valves on the suction and discharge side, whether they be ball or flap type, often require frequent attention. Clogging material will accumulate under the valve seats and around the valves and may cause the pump to stop delivering completely. The valves should, therefore, be inspected periodically. Poor valves may swell and stick, or the rubber may soften or become worn down by gritty material to a size that can be forced into the pump or piping.

The Centrifugal Pump

Centrifugal sludge pumps cannot, like the plunger pump, handle sludges containing large amounts of gas or air. If there is too much sludge gas and air present, the centrifugal pump becomes gas-bound. Therefore, it can readily be seen that this type of pump is not as adaptable for use where there is a suction lift or where air or gas pockets can exist in suction lines. It is also necessary to prevent air from being sucked in through the stuffing boxes. For this purpose waterseals must be provided. This does not mean that this type pump cannot be used for suction lift duty. On the contrary, there are many centrifugal sludge pumps operating successfully under suction lifts up to fifteen feet.

When suction lift duty is involved, a priming chamber should be provided. This priming chamber must perform the dual service of automatic priming and removing accumulated air and gases from the suction line. Where a suction lift exists, the discharge nozzle of a horizontal centrifugal pump should be on the top side of the volute, either parallel to the floor or in a vertical upright position. If the discharge nozzle faces downward, or is placed on the bottom of the volute parallel to the floor, the pump can not be readily primed because there is no way for the entrapped air and gas in the top of the casing to escape.

In may surprise some to hear that, in general, the so-called non-clog type centrifual pump has not proven very satisfactory for sludge pumping service. The smaller the capacity, the more clogging difficulties could be expected from the concentrated amounts of hair, rags, and stringy material in the sludge. Best results are obtained if the suction line is short. The whirling action induced on the suction side of this type pump is not conducive to trouble-free operation. The impeller motion causes the sludge in the suction pipe to rotate in a whirling or spiral motion for a distance of fifteen feet or more. This whirling action will often twist and enmesh the concentrated hair, rags, and stringy material in the sludge into ropes, or wads, which will then clog the impeller of so-called non-clog pumps. Another objection is that the centrifugal force at the suction eye of the impeller may partially dewater the sludge and thus cause clogging.

Centrifugal pumps perform best under positive suction head conditions. This type pump is preferred by many because its operation is quiet and clean, and there are no ball valves or flap valves incorporated which would need periodic attention.

Force-Feed Centrifugals

In spite of all the inherent weaknesses of the plunger pump, until the development of special force feeding centrifugal pumps, the plunger pump was the best available for pumping sludges, particularly in the small capacity ranges. Numerous attempts were made to design a sludge pump incorporating the good features of both the plunger pump and centrifugal pump. In this direction the best answer today is the sludge pump conceived by the late Walter A. Bell while Plant Superintendent of the Northside Treatment Plant, Chicago, Illinois. This sludge pump is a modification of the centrifugal pump and is known today as the "scru-peller" sludge pump. This pump, however, has the inherent priming weakness of the centrifugal pump. This objection is overcome by the use of proper priming equipment. It has all the advantages of the centrifugal pump plus the ability to pass solids better than any other pump without clogging. Although the pump was designed for handling sludges, it has been used successfully at Army posts since 1934 for pumping raw, unscreened sewages.

The "scru-peller" pump has a two-screw conveyor which gives positive feed to a two-port impeller, thus eliminating the danger of partial sludge dewatering at the suction eye of the impeller. Cutting devices are provided in the conveyor housing to cut rags and other material into sizes that will pass through the pump. Cutting devices are also provided on the back of the impeller to prevent packing at this point. The suction nozzle is at right angles to the conveyor to prevent a whirling motion in the suction line. Bearing supports are provided at each end of the pump, as in plunger pump design, to absorb the shock imposed by the cutting load. If only one bearing was provided, the cutting load and uneven sludge concentration would impose too severe a load and strain on the bearing and shaft. Likewise, a two-port impeller is provided instead of a single vane impeller, because it would be impossible to balance a single vane hydraulically. The changing consistency of the sludge would cause undue vibration and whipping of the shaft. The operation of this pump is quiet. It is clean, because packing troubles are corrected in the design features. Having no valves, it is free from clogging and other ball and flap valve troubles.

The Sludge Piping System

Now that we have covered the advantages and disadvantages of sludge pumps, let us consider the factors that a well-designed sludge pipe system should incorporate:

1—A positive suction head is more desirable than a suction lift, regardless of the type of sludge pump used. Positive suction heads will minimize the difficulty of moving heavy sludges at the beginning of the pumping period.

2—The suction line should be as short as possible. The pipe

line should be entirely horizontal or slope towards the pump or rise vertically and then horizontally into the pump. The suction line at the point entering the pump should never be lower than any other point on the suction line. (See sketch.)

3—The number of bends should be at a minimum. Elbows and tees should have long radius bends to minimize stoppage.

4—The suction inlet end should be located on the side of the sludge well to prevent formation of a vortex and, as a result, prevent flow of air into the suction line. A suction inlet in the bottom of the sludge hoppers is likely to be clogged by tools dropped into the hopper.

5—Foot valves, float valves and check valves should never be used on the suction side of the pump.

6—A combination vacuum and pressure gauge should be provided on the suction side, and a pressure gauge on the discharge side of the pump. These gauges will indicate if clogging troubles are on the suction or discharge side and will indicate a build up in pumping head that may be taking place due to sludge caking (sludge ring) in the pipe lines.

7—The check valves on the discharge side of the pump should be placed near the top of the vertical run or, preferably, in the horizontal section if possible. (See sketch.) The position of the valve should be such that when the pump is shut down undue amounts of grit and other foreign material in the sludge will not settle and pack on top of the flapper and prevent the check from opening when pumping is again started.

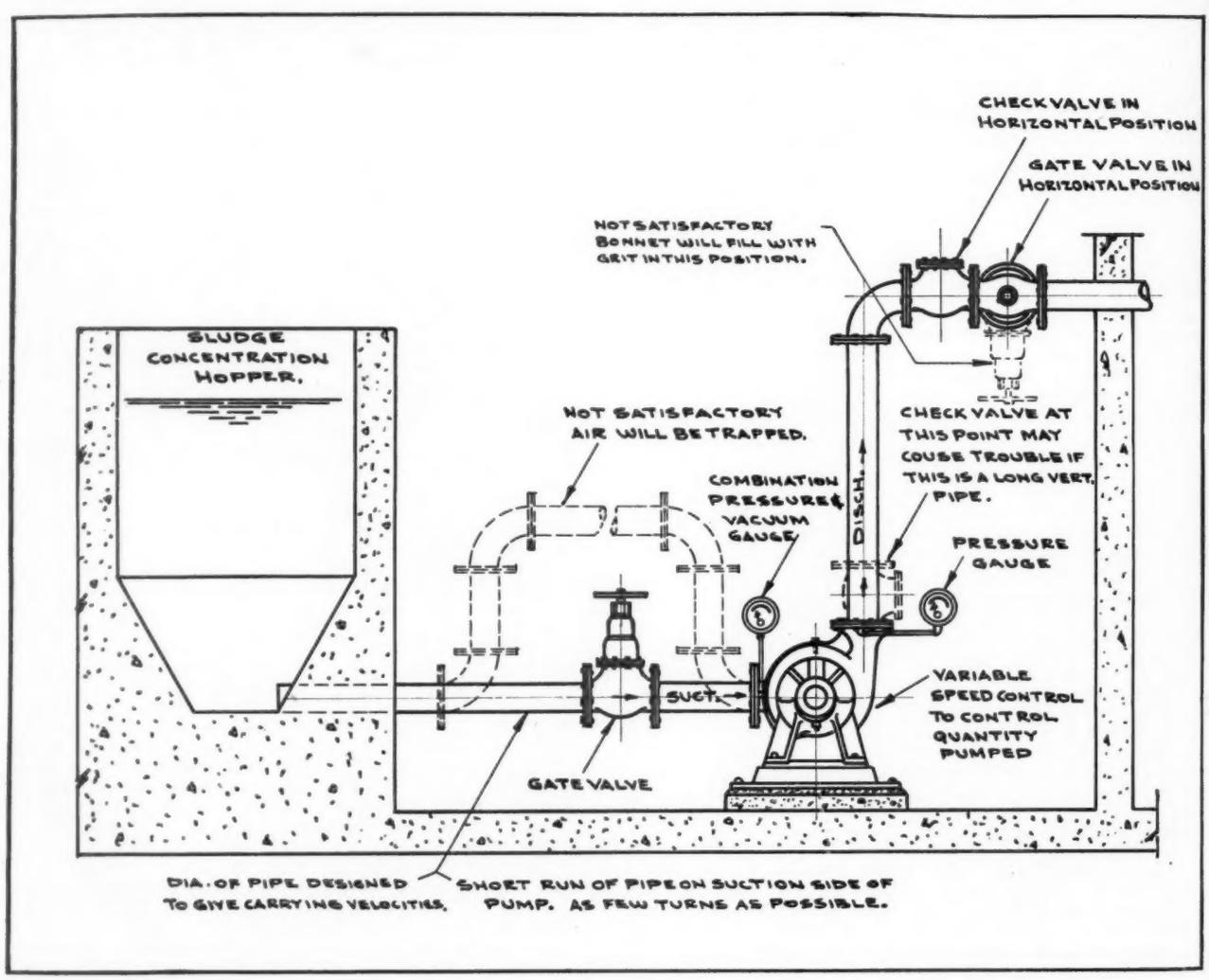
8—Pipe sizes on the suction and discharge side of the pump should be selected to assure scouring velocities (not less than 1 f.p.s.) in the sludge lines. Self-cleaning velocities will prevent or minimize sludge caking on the inside of the pipe. If the sludge line is too large to give cleansing velocities, the sludge will cake on the inside of the pipe line. In time this sludge cake will slough off and in all probabilities clog the line if not the pump.

It is difficult to understand why most of the sludge lines now in use, where the sludge is pumped, were not designed to fit the pump capacity and also give cleansing velocities. We would not think of designing a sewer with a velocity less than 2 f.p.s., even though the solids content is only 0.1 per cent. Yet sludge lines are built with velocities less than 0.5 f.p.s., handling concentrated solids as high as 6 per cent or more.

On a gravity system, or the sludge withdrawal system of Imhoff tanks, there is generally little trouble in the use of large sludge pipe lines, because normally the sludge lines are short and adequate head is available so that full opening of the gate valve will give high scouring velocities. But on a pumping system, the capacity of the pump and size of the sludge line will govern the velocity in the pipe.

In referring to the hydraulic tables it will be noted that in order to get a minimum velocity of 1 f.p.s., the approximate pump capacity for a 4-inch line should be 40 g.p.m.; for a 6-inch pipe, 90 g.p.m.; for an 8-inch pipe, 160 g.p.m.; and twice as much if a velocity of 2 f.p.s. is required. Slow velocities will also cause the heavier material to roll along the bottom of the pipe line. One can picture this rolling action enmeshing hair, rags and stringy material in the sludges and forming wads that may clog the pipe line or valves on the plunger pump.

Arguments generally presented are that 6 inch, 8 inch, and 10 inch sludge pipes must be used to pass the concentrated material and prevent clogging. The fallacy of this argument is that it


CHECK VALVE IN HORIZONTAL POSITION
GATE VALVE IN HORIZONTAL POSITION
NOT SATISFACTORY BONNET WILL FILL WITH GRIT IN THIS POSITION.
SLUDGE CONCENTRATION HOPPER.
NOT SATISFACTORY AIR WILL BE TRAPPED.
COMBINATION PRESSURE & VACUUM GAUGE
DISCH.
CHECK VALVE AT THIS POINT MAY COUSE TROUBLE IF THIS IS A LONG VERT. PIPE.
PRESSURE GAUGE
SUCT.
VARIABLE SPEED CONTROL TO CONTROL QUANTITY PUMPED
GATE VALVE
DIA. OF PIPE DESIGNED TO GIVE CARRYING VELOCITIES.
SHORT RUN OF PIPE ON SUCTION SIDE OF PUMP. AS FEW TURNS AS POSSIBLE.

Sketch Illustrating Some Good and Some Not-so-Good Features of Sludge Pump Installations
Installation of "Scru-peller" Sludge Pumps at Lebanon, Pa.

augments clogging troubles. If a plunger pump is used it is questionable if its ball valve chambers will pass a 1 inch sphere let alone a 5 inch or 6 inch sphere, and we know that match sticks will cause plunger pumps to lose their prime and cause a reduction in pump capacity due to slippage. If a "scru-peller pump" is used, whatever reaches the pump that is cuttable will be cut up and passed through the pump. Nevertheless, slow velocities cause sludge caking to build up on the inside of the pipe. In time this scum will break loose and plug the sludge lines usually at a bend, fitting, or valve.

Causes of Capacity Loss

Perhaps you have noted that the pump sometimes does not deliver its rated capacity. Let us analyze the reason for this condition: In the case of plunger pumps, the valves may have been worn to an extent that they cause too much slippage. Then again, sludges when subject to a suction lift or vacuum may release gasses to an extent that the pump may be pumping gobs of air followed by slugs of sludge.

We know that primary sludges have a varying degree of moisture. The moisture content in the sludge will generally be lowest at the beginning of the pumping cycle and will increase progressively to the end of the pumping cycle. During any cycle of pumping, the moisture content may vary from 90 per cent to 99 per cent. Sludges which have a moisture content of only 90 per cent will have a very high friction factor compared with sludges of 99 per cent moisture content. It is for this reason that during the first two or three minutes or more of any pumping cycle it is hard to get the sludge moving. The friction loss may be five to ten times greater than the friction loss during the balance of the pumping cycle.

It is generally easier to pump sludges having solids contents of less than 7 per cent. Above this point, depending on the character of the sludge, and particularly if it is around 10 per cent, you might have less trouble if you shovel it. Another point to remember is that sludges from one plant may be more difficult to pump than sludges from another plant, even though the solids content may be the same.

The unpredictable character of the sludge and its changing solids content has frustrated all attempts to establish accurate friction losses in sludge lines. As a result, it is more or less necessary to estimate the total dynamic pumping head. If you wish to increase or decrease the capacity of the pump, the simplest way is to equip the pump with a vari-drive type motor. Such a motor will allow you to increase or decrease the pump capacity by turning a small handwheel.

In speaking to operators where both plunger pumps and "scru-peller" pumps are installed side by side, it is surprising to hear the conflicting arguments that the plunger pump will pump heavier sludges better than the "scru-peller" pump and vice versa. Questioning fails to reveal any substantiating evidence. There is no reason why one pump should be able to pump heavier sludges than the other if both pumps are properly installed and in good operating condition.

Operating Problems—and Their Solution

You have often heard the remark that you should pump sludges at a slow rate to prevent pulling a hole in the sludge blanket. Also that a centrifugal pump will pull a hole in the sludge blanket whereas a plunger pump will not. Operators who made experiments and who took sludge soundings before and after pumping with both types of pumps know that this is not true. A hole might be pulled in the sludge blanket by any type of pump regardless of the pump capacity. The cause of this trouble is sludge arching, and failure to flow freely to the intake line.

The sludge may arch over the hoppers, around the sludge pipe in the hopper corners, or the hoppers may be too large with flat slopes and of improper design. Sometimes frequent pumping will prevent arching or the pulsating effect of the plunger pump will break part of it loose. The best answer is to squeegee, otherwise the breaking loose of the arched sludge may allow the gas bubbles to float the sludge blanket to the tank surface. If this should occur, hosing will make it settle readily.

Squeegeeing the hoppers will also reduce the pumping time on rectangular clarifiers, and it will reduce the amount of water formerly pumped to the digester. The less water pumped to the digester, the smaller will be your supernatant disposal problem. Another good way to minimize your supernatant problem is to draw the sludge into a concentration tank. After an adequate settling period decant the clarified liquor and then pump the concentrated sludge. If the sludge mixture is allowed to stay in the concentration tank too long without any stirring, you may find the supernatant on the bottom and the sludge floating on top. The best way to solve the supernatant problem is at the original source, in the undigested sludge, where the liquor does not have the toxic effect that it has when it leaves the digester.

Where plunger pumps pounded excessively, air snifter valves have been placed on the suction side to form an air cushion within the pump cylinder. This does a good job in overcoming pounding, but it is not recommended. Its evil is that you are sitting on a potential volcano that might go off any minute because while you eliminate pounding, you are also pumping a certain amount of the air with the sludge into the digester, making possible an explosive mixture.

Perhaps you have been faced with the problem of prime failure. If it is a centrifugal pump with primer, check your priming equipment for leaky gaskets, sticky valves, or stuck floats. Also, make sure that seal water is flowing to the stuffing boxes. If it is a plunger pump, leaky packing might have to be replaced or tightened. Often the trouble may be a clogged line, or the suction pipe may be sheared off where it enters or leaves a wall.

Perhaps you are having trouble with a check valve at the foot of vertical riser pipe that is being clogged by grit and other material settling on top of the flapper. If the check valve cannot be relocated near the top of the vertical riser pipe or in a horizontal section, you may find that a clear water flushing connection on the suction side between the pump and gate valve of great help to you. By flushing the pipe line under pressure after each pumping you can force the grit and other material to a point where it will not cause any trouble. This flushing connection will also be a great help in case it is necessary to dismantle the pump or clean the ball or flap valves. It is much nicer to work on a pump full of clear water than sludge. It should be borne in mind that this flushing connection should be made in accordance with cross-connection requirements of the State Department of Health.

WATER SERVICE AND SEWER RENTS

The following interesting decision is reported by the Municipal Legal Information Service of the New York State Conference of Mayors and Other Municipal Officials:

"On October 11, 1940, the Court of Appeals, Richmond county, Ohio, held that the city of Mansfield had authority by ordinance and rules and regulations issued thereunder to shut off water at premises which are delinquent in their sewer rental payments. Pointing out that it is well settled that a city may shut off water for nonpayment of a delinquent water bill, the Court considers the direct question involved in this case of the power of a city to discontinue one service for failure to pay for another service, and holds that the sewer and water systems are so closely related as to be considered one transaction as the operation of the sewage system is dependent upon the water supply, therefore, it is reasonable to shut off water for nonpayment of a delinquent sewer rental bill. The court cites and relies upon the case of *Dodd* v. *City of Atlanta*, 113 S. E. 166, which reached the same decision as was reached in the instant case. *Gatton* v. *City of Mansfield*."

A RAPID METHOD FOR DETERMINING SLUDGE SOLIDS

The Sludge Triangle Procedure

By GEORGE E. SYMONS, Chief Chemist, and STEPHEN R. KIN, Assistant Chemist
Buffalo Sewer Authority, Buffalo, N. Y.

IN the January, 1942, issue of WATER WORKS AND SEWERAGE[1] there appeared a discussion of "The Sludge Triangle" as a key to a rapid method for determining sludge solids. In order to make that technique more readily available, this article has been prepared. The theory, experimental development and results are to be found in the original article[1] and, therefore, are omitted here. But, as an introduction, facts drawn from the previous article are presented.

1. It is possible, by use of a special "sludge triangle" graph, to estimate *any two* characteristics of a sludge if the volume of filtrate liquor from laboratory vacuum-filtration of a chemically treated sample, and *one* other characteristic, are known. These characteristics are per cent solids, per cent volatile matter and specific gravity.
2. The method for determining the solids content of a sludge depends on the treatment of a measured sample of sludge with known quantities of lime and ferric chloride, measurement of the volume of filtrate resulting from vacuum filtration of the treated sample, and determination of the specific gravity of the untreated sludge sample. It is possible to perform both tests in ten minutes, after which the total solids and volatile matter content can be estimated with a reasonable degree of accuracy through use of a graph known as the "Sludge Triangle."
3. The per cent solids content may also be estimated from volume of filtrate or specific gravity, if the approximate volatile matter content of the sludge is known. Or, the volatile matter may be estimated from the volume of filtrate liquor or specific gravity, if the total solids content is known. And, specific gravity may be estimated, if total solids and volatile matter content are determined.
4. This simple method is particularly advantageous in plants using chemical conditioning of sludge where the quantity of conditioning chemicals used is dependent to some extent on the volume of water associated with the sludge and/or its content of volatile matter.

Procedure

Filtrate Volume

Measure 200 ml. of well-mixed sludge in a 200 ml. graduate (calibrated to deliver 200 ml. volume of water). Pour the sludge into a 400 ml. beaker that has been rinsed with water and drained, but not dried.

Add 10 ml. of lime reagent containing 0.1 gram of available CaO per ml. Mix well with a flat policeman. Add 5 ml. of ferric chloride reagent containing 0.1 gram of $FeCl_3$ per ml. Mix again.

Place a No. 615 crepe surface filter paper, or equal, on a 3½ inch Buchner funnel, and insert the funnel in a 500 gal. ml. filtering flask. Wet the filter paper with water, apply vacuum until the free liquid has been removed from the funnel, then empty the filter flask.

Pour the conditioned sludge into the Buchner funnel, using a flat rubber policeman to remove drops of the sludge sample adhering to the walls of the beaker.

Apply the vacuum to the flask. When the break-through of air is noted, carefully press the surface of the filter cake with the flat top of a mushroom stopper, or other flat object, in order to close cracks in the cake and secure full effect of the vacuum. Maintain the vacuum and continue pressing the cake until the rate of passage of liquor through the Buchner funnel is less than one drop every five seconds. To continue the vacuum beyond this point may produce an evaporation of liquid sufficient to interfere with the accuracy of the test.

Pour the filtrate from the vacuum filter flask into a 200 ml. graduate (preferably the same as used in measuring the original sludge), and note the volume of the filtrate liquor.

Determination of Specific Gravity

For the determination of specific gravity use a 500 ml. Erlenmeyer flask to reduce the error attendant with use of smaller samples. Into the neck of the Erlenmeyer flask insert a special rubber stopper (made of a No. 7, one-hole stopper and half of a No. 5, one-hole stopper, as shown in Fig. 1). Weigh on a laboratory torsion balance, to the nearest 0.5 gram.

To determine the specific gravity, pour a well mixed sample of sludge into the tared Erlenmeyer flask and stopper it, forcing excess sludge out through the glass tube. Rinse the outside of the flask. Hold a finger over the end of the glass tube and shake the Erlenmeyer flask in a vertical plane with a rapid upward motion and a slow downward motion. This technique increases gravitational force and causes small bubbles, entrapped in the sludge, to rise to the top. After shaking about 50 times in this manner, remove the special stopper and add sludge to the flask until full. Replace the stopper in the flask and force out excess sludge. Wash the Erlenmeyer flask, wipe the outside and weigh. The weight of the sludge divided by the weight of the same volume of water required to fill the flask is the specific gravity.

Use of Sludge Triangle

From experimental study, it was possible to show the interrelation of all factors affecting the release of water from a chemically treated sludge; namely, per cent solids, per cent of volatile matter and specific gravity, as related to ml. of filtrate obtained from the sludge that had been treated as described above. The data, when plotted, produced lines within a wedge shaped triangle. This graph, designated "The Sludge Triangle," is shown in Fig. 2.

The useful applicability of "The Sludge Triangle" depends upon its accuracy when compared to the present standard method[2] of evaporating samples to dryness and weighing. To obtain such a comparison, the proposed method was run in parallel[1] with the standard method for a period of 28 days.

This comparative study indicated the average error in total solids by the new method to be only 0.02 per cent of the standard method. (This agreement is somewhat surprising since the proposed method actually determines the suspended and flocculatable solids, and does not include the dissolved solids in the expressed liquor. Total solids should be at least 0.1 to 0.3 per cent higher because of this dissolved matter.) In the estimation of volatile matter content, "The Sludge Triangle" is less accurate. The average error during the four-week period was 2.43 per cent, with wider variations in individual samples than in the case of

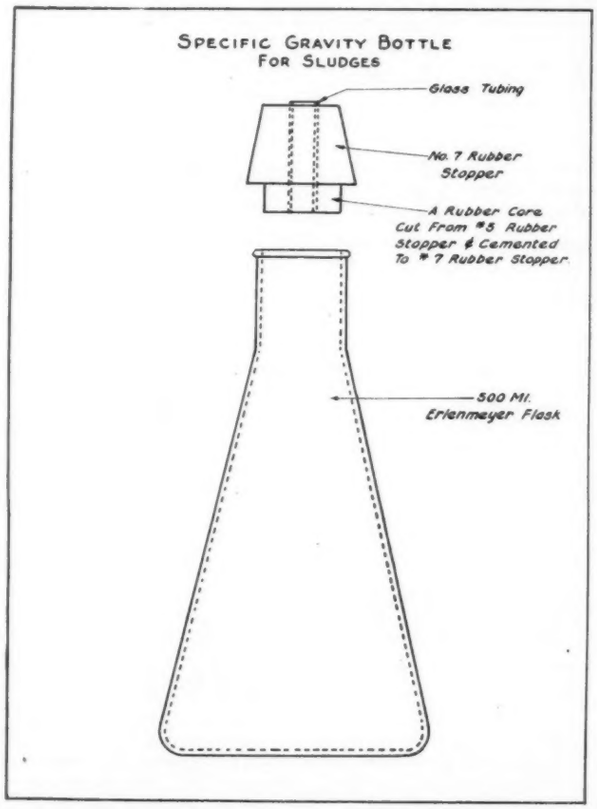

SPECIFIC GRAVITY BOTTLE
FOR SLUDGES
Glass Tubing
No. 7 Rubber Stopper
A Rubber Core Cut From #5 Rubber Stopper & Cemented To #7 Rubber Stopper
500 Ml. Erlenmeyer Flask

Fig. 1—Flask for Determination of Specific Gravity of Sludges.

total solids. It appears that the errors are greater when the concentration of solids is below 3 per cent.

These errors are based on the assumption that the standard method is correct. However, considering the difficulties of sampling sludges for the determination of total solids and volatile matter (by evaporation and ignition), it is not surprising that there are some differences between the two methods. It has been shown that sampling[3] is important in sludges of this type.

Variations in Technique

(1) In special cases, it was found that certain variations in technique could be employed. For example, when the solid concentration is above 8 or 10 per cent, and a sample of sludge does not pour cleanly from a graduate in which it is measured, the graduate may be rinsed out with a 20 ml. of water from a pipette and the rinse water poured into the beaker containing the sludge to be conditioned and filtered. After the filtration, 20 ml. is subtracted from the volume of the filtrate readings in order to give the filtrate volume from the original sludge.

(2) Where greater accuracy of measurements is desired, it is possible to weigh the original sample of sludge and then weigh the graduate or beaker from which it is poured into the Buchner funnel. This difference in weight when corrected for specific gravity will give the actual volume of sludge conditioned and filtered. Inasmuch as the test depends upon the use of a standard 200 ml. sample, any variation from that volume, as determined by difference in weight, according to this method can be applied to the filtrate volume reading in order to produce a correct reading.

(3) For sludges of greater than 8 per cent solids, the gravity may be determined by diluting the sample with an equal volume of water. This procedure simplifies the removal of entrained air bubbles. In this case the specific gravity of the original sludge is calculated according to the equation:

$$(\text{Sp.G.} - 1) \times 2 + 1 = \text{Sp.G. of original sludge}$$

This technique will eliminate some of the objections to the determination of specific gravity cited by Smith.[4]

(4) To further simplify the technique, and increase the accuracy of the test, determine the specific gravity in a 200 ml. Erlenmeyer flask and use the sample thus weighed as the sample ot be chemically conditioned and filtered. The gain in accuracy of determining the amount of sample filtered would off-set the

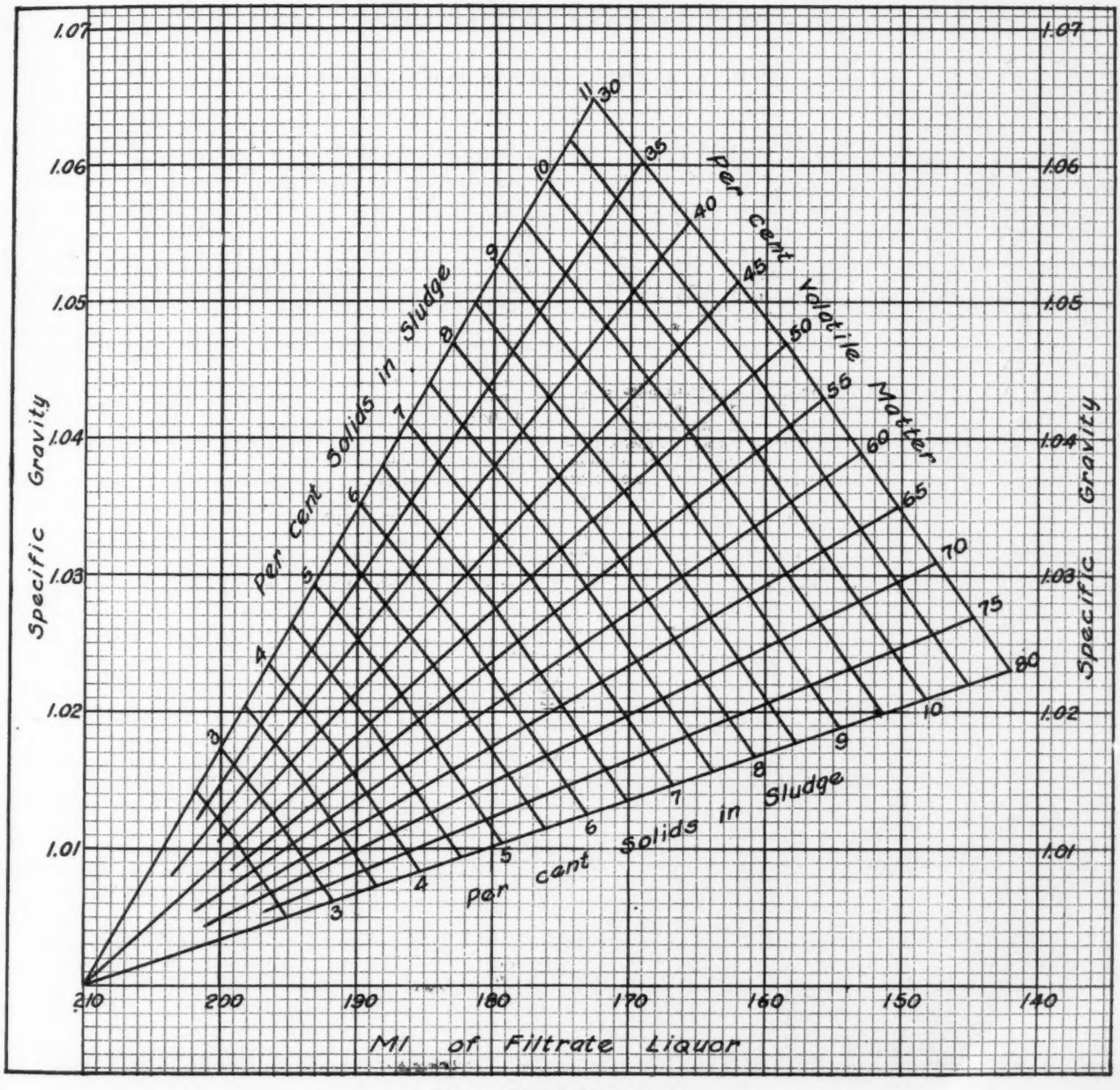


Fig. 2.—The Sludge Triangle.
A Graph of Interrelations of Three Sludge Characteristics.

decrease in accuracy of the specific gravity determination on the smaller sample. (If the 200 ml. flask does not hold exactly that volume, the graph must be reconstructed.)

(5) If the volatile content of the sludge is not known, determine the specific gravity of the sludge and the volume of the filtrate liquor. From these, the per cent solids in the original sludge sample and the per cent volatile matter in the sludge may be determined from the graph. If the volatile content of the sludge is known, or approximately known, it may be unessential to determine the specific gravity in order to obtain the approximate concentration of solids in the sludge.

A Thorough Study Desired

This particular "Sludge Triangle" was developed on raw and digested sludge from the Buffalo sewage treatment plant. Sludges from other sewage disposal plants may exhibit different characteristics in this test and this "Sludge Triangle" therefore may not apply directly. A specific triangle may have to be developed for each particular type of sludge; this may be especially true for activated sludge. It is hoped that the applicability of this test will receive considerable study in other sewage treatment works, and that its use will be as advantageous elsewhere as it has been in Buffalo.

References

1. G. E. Symons and S. R. Kin, "The Sludge Triangle," Water Works and Sewerage, **89**, 17-23 (1942).
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3. G. E. Symons and B. Morey, "The Effect of Drying Time on the Determination of Solids in Sewage and Sewage Sludges," Sew. Wks. J., **13**, 936-39 (1941).
4. J. I. Smith, "Investigation of Rapid Methods for Sludge Solids Estimation," Sew. Wks. J., **6**, 908-19 (1934).

DETERMINATION OF HYDROGEN SULPHIDE BY SIMPLE METHOD

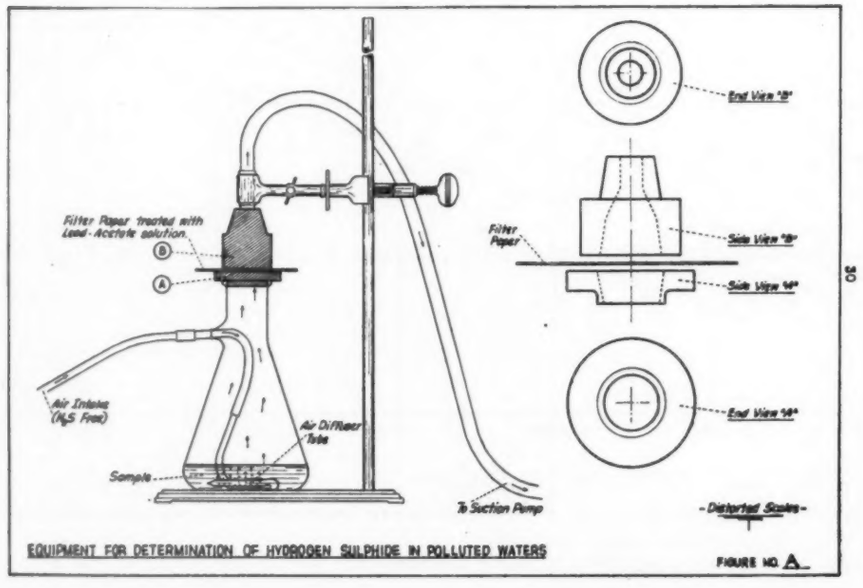
By GEORGE MARTIN, Superintendent of Sewerage

Green Bay, Wisc.

IN MAKING routine determinations of hydrogen sulphide in sewage, sewage gas, and polluted waters it was found that the procedure as described in Standard Methods was not satisfactory, due to the fact that polluted waters and sewage have an iodine demand. Therefore, a modified or special method of procedure was adopted. This special method is based upon the known fact that filter paper treated with a lead acetate solution will darken when placed in contact with hydrogen sulphide. It was found that by making a set of standards, with which any sample might be compared, consistent and fairly accurate results could be obtained.

The Apparatus

The apparatus necessary for making these determinations consists of a standard 500 ml. filtering flask, on the inside of which is placed an air diffuser made of a perforated aluminum tube connected to the flask's side tube by means of a rubber hose. On the outside of the side tube there is attached the rubber air intake hose. The lead acetate paper is held in place on the top of the suction flask between a rubber ring "A," which is a standard Gooch crucible holder for an ordinary two-inch funnel, and a standard Gooch crucible holder "B," as is ordinarily used with a filter flask. "A" and "B" are held together by a utility clamp fastened to a ring stand. The rubber hose which is attached to the glass tubing of "B" is connected to a suction device.



EQUIPMENT FOR DETERMINATION OF HYDROGEN SULPHIDE IN POLLUTED WATERS

FIGURE NO. A

The Procedure

In making a determination with this apparatus the sample to be tested is delivered into the flask directly from a pipette through the aeration tube. Air is then drawn through the liquid for two minutes and by so doing the hydrogen sulphide passes on up through the lead acetate paper, discoloring it. The amount of hydrogen sulphide is determined by comparing the colored lead acetate paper with the standards and converting the results into the desired units.

In order to operate this apparatus satisfactorily it is necessary that there be at least 100 ml. of liquid in the flask. Thus, if the sample being tested is high in hydrogen sulphide, it becomes necessary to dilute it with hydrogen sulphide free water. If it is desired to have the final results in p.p.m., this figure is arrived at by multiplying the color comparison in mg. by 1000 (mg. per liter = p.p.m.) and dividing by the ml. of sample used.

Example: Sample = 10 ml.
Volume of water added to flask ahead of the sample = 90 ml.
Color comparison = 0.05

$$\text{p.p.m.} = \frac{0.05 \times 1000}{10} = 5 \text{ p.p.m.}$$

Gas may be tested for hydrogen sulphide content by passing a known volume through the above described apparatus.

Test Papers and Standards

The lead acetate paper is prepared by soaking filter paper in a 10% solution of lead acetate and drying in an oven until approximately 10% to 15% of the moisture remains in the paper. The paper must then be kept in an air-tight container.

Standards are made from a solution of hydrogen sulphide prepared by generating hydrogen sulphide in distilled water from iron sulphide by the addition of dilute sulfuric acid, the solution being standardized by iodine titration.

[Note: The apparatus herein described won for the author first prize in the Gadget Contest conducted at the recent Convention of the Central States Sewage Works Association.—Ed.]

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Converting a Loss Into a Profit!

Instead of the expense of incinerating or burying sludge cake from filters or drying beds, an ever increasing number of sewage plants are disintegrating their sludge cake with a Royer so that it can be used for readily marketable fertilizer, thus realizing a profit and saving manpower.

The Royer shreds, aerates and further dries sludge, readily handling cake with moisture content of 50% and more. It removes sticks and stones and loads directly into trucks or onto piles. Compost, soil, sand, manure or chemical enriching materials can be thoroughly mixed into the sludge in any proportion in the same operation.

Here's how it works. Material loaded into the hopper is fed to a belt which rapidly revolves at a 45° angle and upon which are rows of sprigs, or teeth. Sludge cake is raked and worked over by these hundreds of teeth until it is reduced to small particles that are ideal for top dressing, for working into the soil or for blending with other soil building materials. The particles can be adjusted from pea size to larger, by adjusting a sweep on the discharge end. A deflector controls the arc of the discharge throw.

Saves 3 Ways for Municipalities!

The Royer is used by many cities in parks, public golf courses and cemeteries to shred, aerate and enrich compost and soil. Cities with greenhouses or conservatories use them to prepare bench and potting soils. The Royer Junior can be lifted onto and used right in the bench. Many cities use them to mix clay and cinders, sand and clay or to mix in calcium chloride for tennis courts, running tracks, horseshoe courts, etc. Not uncommonly cities use a Royer for all three jobs, various departments sharing the purchase cost or renting them from the sewage plant.

Cities with extensive park systems frequently absorb the entire prepared sludge from their sewage plants; beautiful lawns and foliage resulting. Other sewage treatment plants take care of their parks and have enough over to supply local golf clubs, florists and truck gardeners. The success enjoyed by Milwaukee, Wisconsin and Dayton, Ohio in marketing prepared sludge as fertilizer needs no elaboration.

A Size and Capacity for Every Plant!

Royers are available in twelve portable and stationary models with electric motor, gasoline engine and belt-to-tractor drives. Send for file of data by recognized authorities on value and use of sewage sludge for fertilizer.

THE ROYER

Kenosha, Wis. Sewage Treatment Plant uses Model NSB-2 to shred, mix and aerate sludge for use as fertilizer and lawn top dressing in the city parks.

Green Bay, Wis. Sewage Plant profits from the use of a Royer Sewage Sludge Disintegrator.

Model "SO", gasoline engine driven, mixes and shreds soil and compost for Wilmington, Del. park system.

Royer Model NSB-4, electric powered, conditions sludge cake, loading shredded product directly into truck for Charlotte, N. C. Sewage Plant.

REDUCING COST OF SLUDGE REMOVAL

Experiences at Aurora, Ill., with a "Saddle-Bag" Tractor

By WALTER A. SPERRY, Superintendent
The Aurora Sanitary District,
Aurora, Illinois

DURING the summer of 1940 the Aurora Sanitary District constructed eight new sludge drying beds under a W. P. A. contract. This increased the sludge drying area from 50,000 to 96,250 square feet, which gave 1.44 square feet per capita on the original design basis of 67,000 population and 1.96 square feet per capita on the basis of the present population of 49,000. This increase was desirable due to the frequency of winter cleans caused by increased loadings on the plant and the addition of secondary sludge to the digesters in 1937.

Sludge Removal Methods Evaluated

New drying bed construction involved the selection of a method for removing sludge. Two factors entered in. The first was the cost of trackage versus a more modern method of mechanical removal. The second revolved around the sponsor's credit in the W. P. A. set-up for the disposal of some 3,500 cubic yards of excavation. If contractor's equipment was hired to do this work it would cost more than if the sponsor had in hand dirt moving machinery where the only expense would be gasoline, motor oil and the operator's wages. This led to the consideration of abandoning tracks in all beds and substituting therefor the "saddle-bag" tractor originally planned by Mr. W. B. Walraven of Springfield, Ill., and described by him in an article, "A New Device for Handling Dried Sludge," in *Water Works and Sewerage* of February, 1934. General investigation indicated that this was, by far, the best device available. Some pressure was brought to bear to adopt a self-propelling bucket elevator to pick the sludge from the beds and discharge it to a following truck. Also it was urged to purchase a tractor with a yard shovel attachment in front, similarly working with a truck.

These devices were not suitable, first, because of the damage to the sludge beds in attempting to pick up mechanically a thin layer of material from a relatively thin layer of sand without disturbing the gravel underneath; second, because of the bulk of the equipment and the cutting up of the bed by both the tractor and truck; third, a truck was not suited to travel over the sludge storage pile; fourth, all of these devices were expensive and of no value for any work about the plant; and fifth, the required space for storage in the interim period was not available.

Advantages of the Crawling Tractor

The Springfield tractor, on the other hand, was self-contained. Equipped with caterpillar treads enabled it to travel over the sludge storage pile under quite adverse conditions, i.e., when wet and soft.

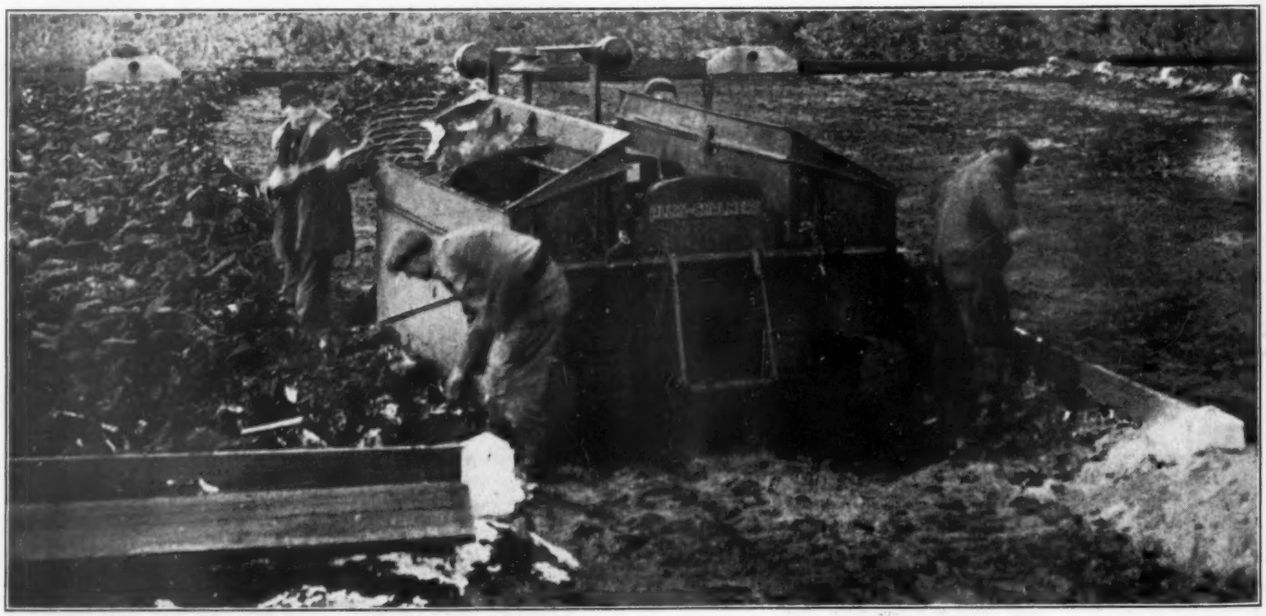
Due to its ability to mount and crawl over the storage pile, the "saddle-bag" tractor appeared to be especially useful in making the most of limited storage areas. It has also proved useful for the disposal of grit from the screen house to the storage space. The machine can be equipped with a bull-dozer for snow problems in the winter, for trimming the sludge pile and for grading gravel roads or pulling stumps. The tractor required small storage space and has generally offered all the facilities of a man carrying two buckets where the load could be transported and deposited anywhere the feet could walk.

Considering its adaptability and general usefulness, it seems surprising that but three of these machines are in use to date. The original one is at Springfield, the second at Mansfield, Ohio, and the third here at Aurora, Ill.

Trackage for the new beds would have cost in the neighborhood of three thousand dollars ($3,000). The tractor equipped with the side bins cost two thousand, two hundred and sixty dollars ($2,260). Against this cost its temporary use as a construction unit in building the sludge drying beds saved the Aurora Sanitary District about sixteen hundred dollars ($1,600) over rented equipment for the construction period.

The Unit

The tractor (see cut) is an "M" type Allis-Chalmers caterpillar type machine. It is driven by a 32.4 H.P. engine with four forward speeds, is equipped with starter, and weighs 6,500



The Tractor Being Loaded During a Winter Cleaning Operation
The hard, frozen sludge is first broken up by the "breaking gang," and thereafter easily loaded into the "saddle bags." Note the comfortable loading height of these side-bins.

pounds. Equipped with the bins, it is about 8 feet long, 7 feet wide and 6 feet high over-all. The bins, which have a combined capacity of 3 cubic yards, add another 1,500 pounds for a total weight of 8,000 pounds. It has a bearing of 1,530 square inches. With full bins this gives a pressure per square inch of from 7 to 9.5 pounds, depending upon the moisture content of the sludge. The bins are constructed of 8 gauge metal and the whole device is of such strong and sturdy construction that its life will be many years. The original machine purchased in 1932-33 is still in use at Springfield and in good order.

Performance Records

Before purchase of the tractor, in the period July, 1939, to May, 1940, inclusive, 4,055 cubic yards of sludge were removed from the Aurora beds to the storage pile at a total cost of $2,095.51, or 51.6c per cubic yard. The unit cost varied from 30.6c to 67.7c per cubic yard, as between summer and winter conditions. For this period the standard crew then hired for the cleaning jobs consisted of a team at $10 per day and seven men at 45c per hour. This gave us a daily hired labor cost of $35.20. Experience showed that three 1 cubic yard cars, two men to a car, gave the right balance of work for the team and Fresno scraper used.

The tractor was purchased and went into use in June, 1940. Between June, 1940, and March, 1941, inclusive, 4,933 cubic yards of sludge were removed to the pile at a total cost of $1,057.59, or 21.4c per cubic yard, to which should be added two cents per cubic yard for tractor oil and gasoline. The tractor crew consisted of four men at 45c per hour, or a total cost of $14.40 per day. This is a difference of $20.80 per day for hired labor between the two methods. Note that the gang foreman in the first case is the tractor operator in the second case. He is a plant employe on the regular payroll and not included in either cost estimate. This indicates a saving of 54.8 per cent for the new method.

At the time the tractor was purchased it was assumed that the saving would be in the cost of the track and the reduced price due to the temporary rental to the Government, and that the time of sludge removal might be extended since but four men were lifting sludge against six with the old method. The interesting surprise was that four men and the tractor do at least 90 per cent as much work as six men, due to the fact that the trip to the storage pile is but once for every 3 cubic yards, whereas, formerly each 1 cubic yard lot was pushed by car to the pile by its two man crew, with "waits" for any car ahead to clear switches.

During interim periods the tractor is stored in the screen house and is used almost daily to remove grit. A bull-dozer blade is being planned for permanent mounting for clearing snow from the plant driveways, trimming the storage pile, and for maintenance of the gravel roadways.

Two Minor Objections Appear

Two minor objections to the tractor are that a little more care must be taken to keep the sludge beds well sanded against the disturbing effect of the tractor cleats. The second objection developed this winter when it was discovered that the physical condition of the operator was affected due to shock and jar caused by the frozen state of the ground. Happily this was satisfactorily corrected by the purchase and use of a wide leather belt such as is used by motorcyclists and truck drivers to support the abdominal region.

INSTRUCTIVE WALL PANEL FOR TREATMENT PLANTS

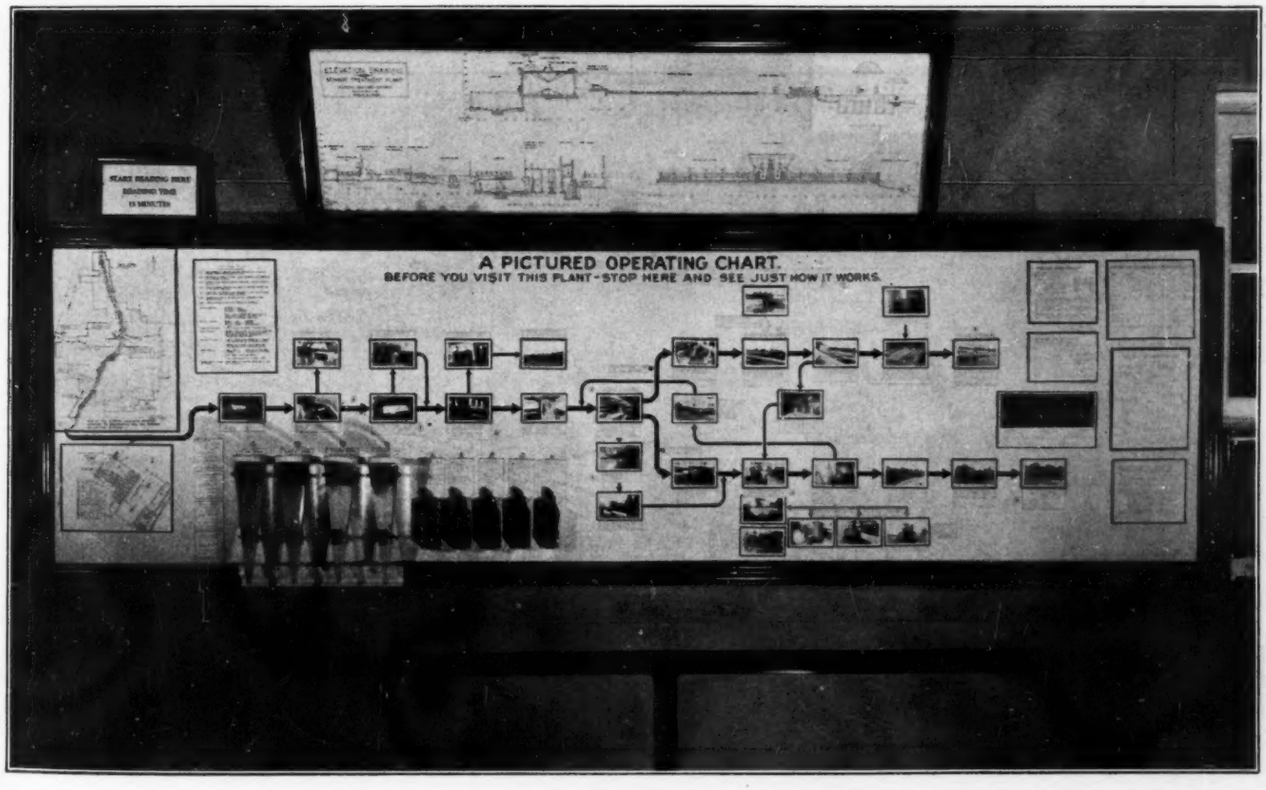
A Picturized Operating Chart with Specimens Attached

AT the Sewage Treatment Plant at Aurora, Illinois, the visitor runs smack into this wall panel designed by Walter A. Sperry, Plant Supt.

The sign reads—"Before inspecting the plant stop here long enough to see how it works. But 15 minutes is required to read all captions."

We are reproducing this picture of Aurora's instructive chart because it seems an ideal method of giving the visitor a preview of what he is to see in looking over the works. Further than that, it is used frequently for the purpose of instructing school classes, Boy Scouts and Girl Scouts who visit the plant.

Photographs are used to show the relationships of each plant unit to the other and its functions are indicated by live specimens of crude, settled, filter effluent and final plant discharge in Imhoff Cones. Samples of sludge "before and after" are exhibited and also petri dishes showing what happens to the bacteria. The whole thing is a great idea and, what's more, saves many words.



A VACUUM FILTER DRESSING RIG

Saves Cloth, Wire and Time

By W. D. SHEETS, Shift Supervisor of Operation
Sewage Treatment Works, Columbus, Ohio

ONE of the greatest time-consuming operations in connection with sewage sludge dewatering by use of vacuum filters is that of dressing the filters. By "dressing" is meant the removal of the spirally wound holding wire and spent cloth for replacement with new cloth.

Filter cloth in this type of service is subjected to severe operating conditions, resulting in a relatively short life requiring frequent replacement. Conditioning sludge with ferric chloride and lime causes deposition of calcium salts and other insoluble compounds in the interstices of the cloth. Although such choked cloths may be rejuvenated by dry scrubbing or by giving a dilute hydrochloric acid bath in place (3% acid or less), the fibers eventually break down from the acid and acid insoluble compounds prevent further treatment. Even ferric chloride when used alone has a similar effect, the deposits consisting of iron compounds which are unaffected by the acid bath.

The total filter installation at Columbus consists of four 8 ft. by 12 ft. filters having an area of 300 sq. ft. each. Individual cloths are approximately 13 ft. by 25 ft., a size that is bulky and cumbersome.

When operations were started at Columbus, a wiring rig of 4x4's, such as described in the manufacturers' instructions, was constructed and used with individual cloths for some time. This was extremely heavy and very hard to anchor properly, requiring constant attention to keep it at the correct angle with respect to the filter drum.

An Improved Rig Developed

A study of the situation was made and the following improvements were believed possible by the design of new apparatus:

(1) Storage and handling of a cnotinuous roll of cloth to eliminate from 1 to 2 feet of waste at each change.

(2) To facilitate the removal of the old wire and to assist in the reapplication of *the same* wire.

(3) Maintain the proper tension in the wire when rewinding.

(4) Satisfactorily braced while in use without requiring a release of the anchorage when correcting for direction of wire pull.

(5) Ease of transportation from one filter to another.

A sketch of the proposed apparatus was made and turned over to our machine shop. Requiring approximately 30 man hours to build it, the mechanism was turned out in record time at an exceptionally low cost.

The accompanying photograph shows the wiring rig in position and illustrates the manner in which the cloth is applied to the filter. A single cloth was used in this photograph to show the comparative capacity of the rig when a full bolt is in place.

Not shown in the photograph, or drawing, is a hand-operated lever put to use when rewinding the old wire. This lever guides the wire into position on the reel (center of rig) and prevents pyramiding. Such pyramiding results in subsequent collapse and loss of tension when rewiring. This lever is mounted on the angle iron member seen just above the wire reel. It moves back and forth in a horizontal plane when in use.

Results Attained

With respect to the improvements listed above the corresponding results were as follows:

(1) Cloth is now purchased in sections having a width of 12 ft. 8 in. and 152 ft. in length. This length is sufficient for six coverings.

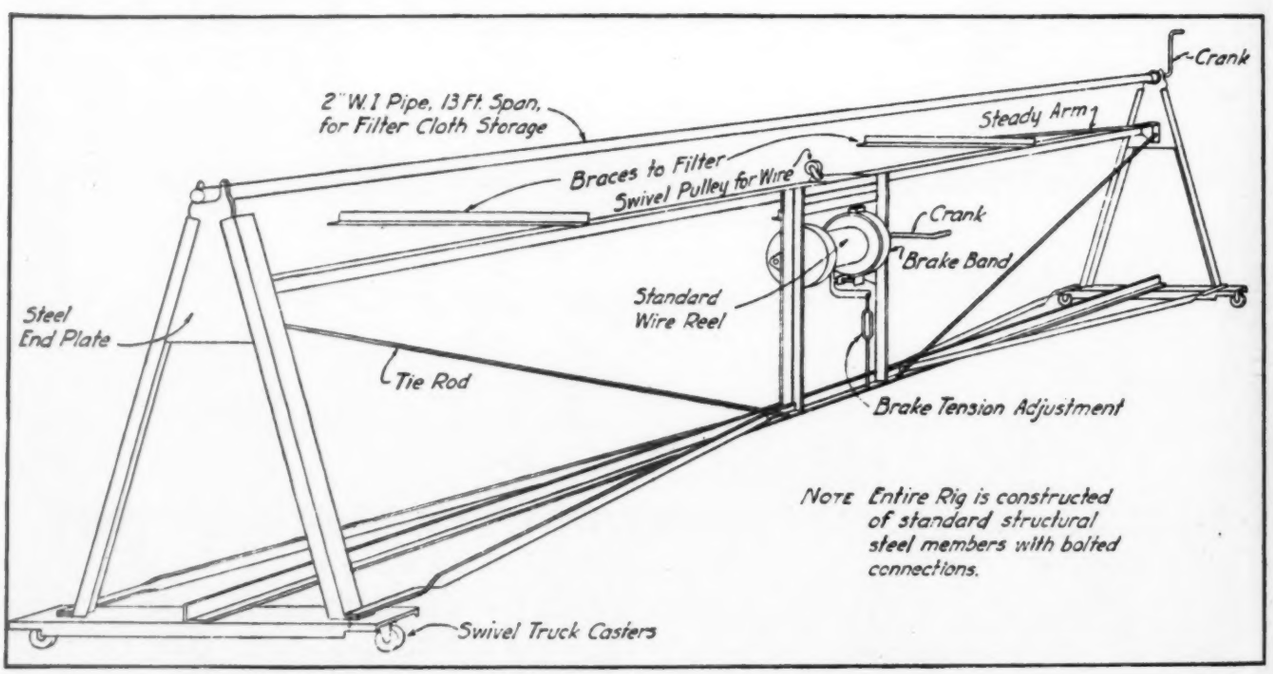
(2) Since the wire used is monel-metal, and subject to deterioration only through wear, its careful removal from the drum and its re-use represents a saving of approximately 1200 feet of wire per re-covering. The only loss is a short section, from the filter drum to the reel on the rig, which is necessary to hold the tension on the entire winding until it has been anchored at the drum.

(3) Any tension desired can be attained through the adjustable brake drum on the reel.

(4) Very rigid bracing resulted, and direction of wire pull is automatically corrected by a swivel pulley directly above the wire reel.

(5) The apparatus can be disengaged, moved to another filter and attached ready for operation in 5 minutes.

This rig is extremely adaptable and has cut the time of dressing from approximately 16 man hours to 6½ man hours per filter. It has enabled the filter operators to change a cloth while attending to their regular operating routine. Several coats of aluminum paint have made it perfectly at home in its present surroundings and it has proved exceptionally satisfactory in all respects.



Sketch showing simplicity of construction of the Columbus rig. Lightness of weight and swivel casters make for easy handling. Note wire saving reel at center.

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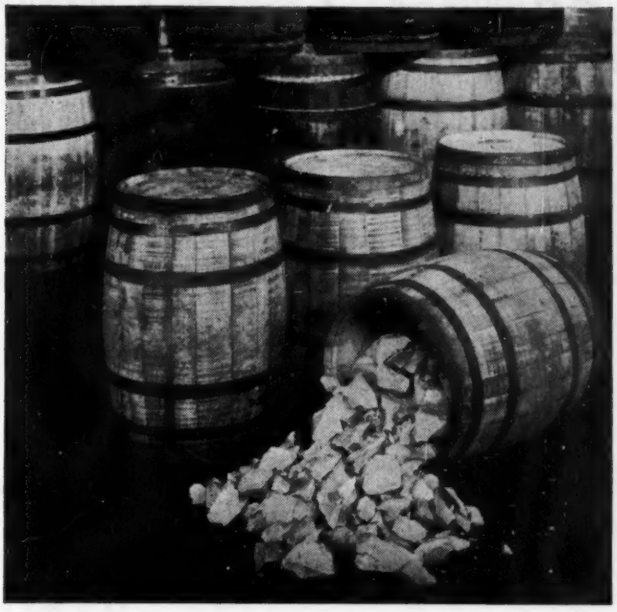

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- Minimum chemical and operating costs.
- Cuts dewatering equipment cost — increases performance.
- Gives higher filtration rate.

FOR SEWAGE COAGULATION

- Greater removal of suspended solids.
- Lower 5-day B.O.D.
- Increased flexibility to meet peak loads and low stream flows.
- Economical effluent improvement.
- Reduction of hydrogen sulphide odors.

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- Forms a compact, quick settling floc with complete precipitation at any pH value above 5. Retains effectiveness in cold weather.
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- In conjunction with lime, removes iron and manganese.
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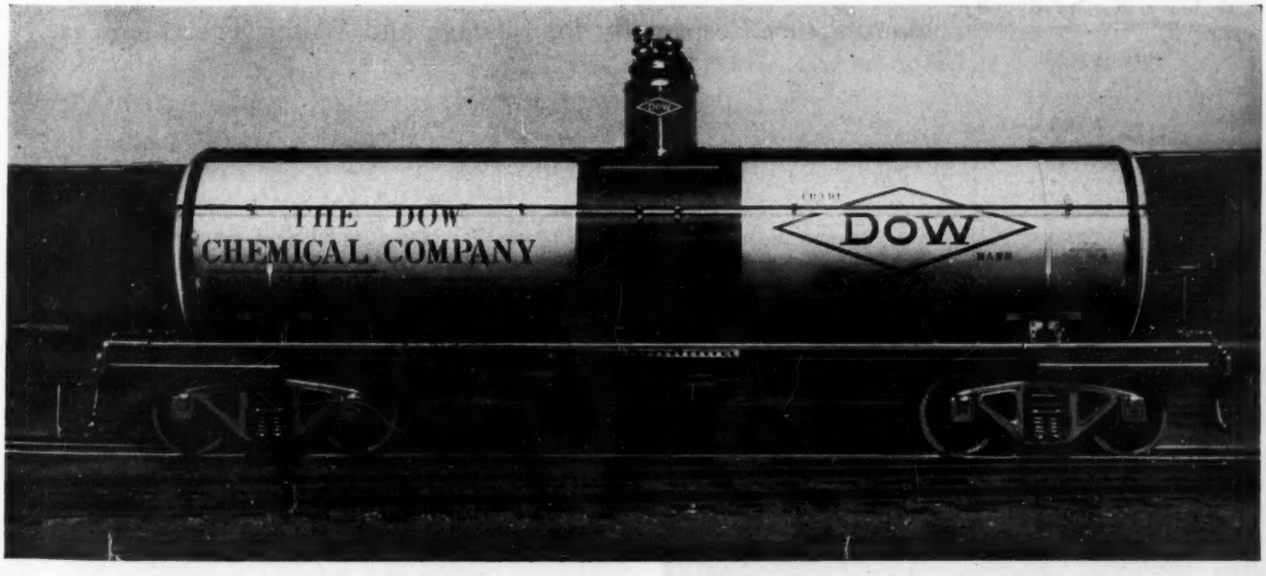
Dow Ferric Chloride 37-47% Solution is shipped in tank cars. Ferric Chloride 60% Crystals are packed in 300 lb. and 500 lb. heavy wooden barrels, permitting storage without deliquescence of the crystals.

Dow Technical Service covering design and operating problems of sewage disposal plants is available upon request to engineers.



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Ferric Chloride coagulates sewage and industrial wastes thus causing more rapid precipitation in sedimentation plants and faster filtering through vacuum filtration systems. It is most effective in the pretreatment of industrial wastes which offer change in characteristics almost hourly.

Experience has shown that Ferric Chloride is also an *economical* coagulant for sewage and wide range of industrial wastes.

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Ferric Chloride provides an inexpensive and efficient method of dealing with plant overloads, and reduces original plant investment by increasing the capacity of the sedimentation plant.

Amount of Ferri-Clor to Be Used

The accepted procedure in determining the dose of Ferric Chloride required to coagulate a given sewage is to set up "jar tests" with sewage to be tested. 2 qt. Mason Jars and stock solutions of Ferric Chloride and Lime, consisting of 10 grams per liter of distilled water, are used. Place one liter of sewage to be tested in each of several Mason Jars. Add to the sewage in each jar, successively larger doses of Ferric Chloride stock solution. Stir all samples thoroughly for several minutes and let stand for 1 hour. Observation of the several samples will determine the best dosage. If lime is required to provide sufficient alkalinity for satisfactory coagulation, follow the same procedure outlined for Ferric Chloride. The amount in lbs. of Ferric Chloride or Lime required equals the number of c.c. used in the selected test × 10 × total sewage flow (m.g.d.) × 8.33.

FOR SLUDGE CONDITIONING

Ferric Chloride is accepted as the agent most efficient from the standpoint of performance and cost for the coagulation of sludge prior to its dewatering in the filter.

Amount of Ferric Chloride to Be Used

Using the Buchner Funnel Test, the time periods required for the vacuum to break with varying quantities of coagulant are recorded. 2 to 3 minutes is satisfactory and 1 to 1½ minutes is very good and should be used for plants where the sludge is held as in batch-mixing.

Various combinations of Ferric Chloride and Lime should be tested until the relative quantities for optimum operation are determined.

FERRIC CHLORIDE

The approximate quantities of chemical to be used in the plant can be determined from the laboratory tests, provided, of course, that the same strength chemicals are used in the plant. The quantity of Ferric Chloride solution in gallons per 1000 gallons of sludge will be 5 times the c.c. used per 200 c.c. of sludge in the test. Likewise, the quantity of Lime in pounds per 1000 gallons of sludge will be 42 times the grams used per 200 c.c. of sludge.

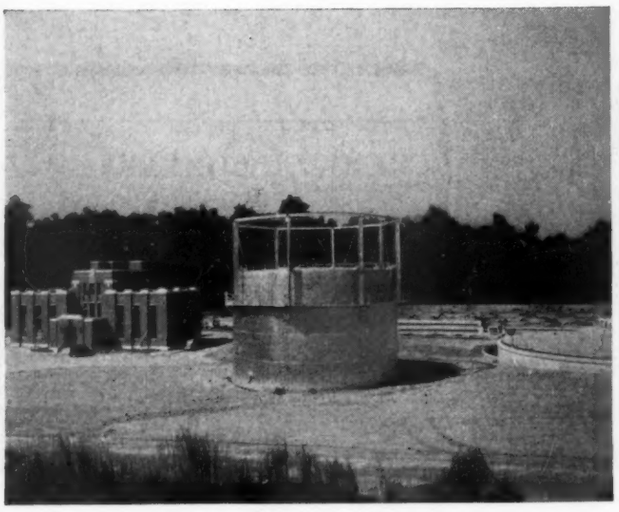
PREPARATION OF FERRIC CHLORIDE SOLUTION

The main difficulty in dissolving Ferric Chloride arises from the fact that the saturated solution is heavier than water. This means that the liquid in a simple container may have a layer of pure water at the top, even with undissolved crystals at the bottom. To overcome this difficulty, three methods have been developed.

1. Automatic gravity circulation by placing the salt on a wooden grid elevated or suspended one-half way in the tank.
2. Mechanical mixing by (a) stirring, (b) by air agitation, and (c) liquid recirculation.
3. Melting: Ferric Chloride melts at 98.6 to 102.2°F. and so can readily be liquefied by relatively small amounts of heat from exhaust or live steam, flue gases, oil, gas or electricity. The dissolved salts can be poured into the water.

Ferri-Clor is ISCO's registered name for Ferric Chloride developed and manufactured especially for Sewage and Water Treatment use.

60% ($FeCl_3$)



ISCO Ferric Chloride is used in America's newest and most modern sewage treatment plants.

FERRIC CHLORIDE

Practical Aspects of Storing and Handling

By L. L. HEDGEPETH and J. M. POTTER

Technical Service Dept., Pennsylvania Salt Mfg. Co., Philadelphia, Pa.

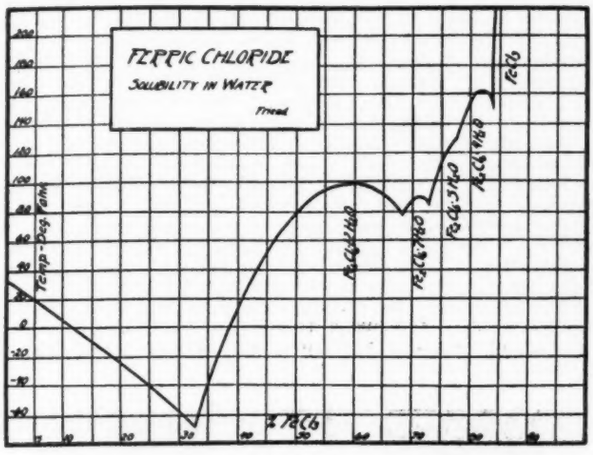
The steady advance in the utilization of chemicals in sewage treatment has created an increasing interest among engineers and municipal officials in the problems involved in their use.

The object of this article is to supply a concise outline of the more significant properties of ferric chloride and effective methods of handling and storing it.

At this time there are three commercial forms of ferric chloride available:

1. *Liquor*—An aqueous solution which is prepared to contain between 39 and 45 per cent $FeCl_3$ by weight to meet exact specifications.

2. *Crystals*—A definite crystal of the formula $FeCl_3.6H_2O$ containing 60 per cent $FeCl_3$ by weight.



Solubility of Ferric Chloride at Varying Temperatures. Note that a 45 Per Cent Solution will Crystallize at About 52 Degrees F.; a 33 Per Cent at Zero.

3. *Anhydrous*—A complete water-free form containing 98 per cent or more $FeCl_3$ by weight.

Liquid Ferric Chloride

Commercial ferric chloride liquor is a dark brown, somewhat oily appearing aqueous solution of varying concentrations. Obviously for the lowest transportation cost, the FeCl content of these solutions should be as high as possible but concentrations are limited by crystallizing temperature conditions during transit or storage. To prevent crystallization the strength of solutions usually varies from 45 per cent in midsummer to 39 per cent $FeCl_3$ in midwinter. Average concentration of shipments over a period of several years has been 42 per cent.

Shipments are made in rubber-lined tank cars holding 8,000 gallons and averaging 40,000 pounds of dissolved $FeCl_3$ per car. The dome of the tank car is equipped with sump and center level discharges, a filling and air pressure pipe with gauge connection and a rubber disk safety valve which relieves at gauge pressures exceeding 25 pounds. The car is unloaded by attaching a rubber hose to the discharge connection and siphoning in case of low level storage tanks or by applying air pressure up to 25 pounds where a lift is required.

The maximum lift by air ejection is limited to 40 ft. If higher lifts are necessary a suitable pump should be provided.

Ferric chloride liquor (referred to in the trade as liquid ferric chloride) is easily handled and is usually the most economical form for use by the large consumer, who is reasonably near a source of supply. However, it has the disadvantage of requiring transportation costs on its 58 per cent (average) water content, railroad siding facilities, and storage tanks for one or more cars.

Storage Tanks

Except for its strongly corrosive nature, ferric chloride liquor offers no storage hazard, the only storage problem being provision of sufficiently large ferric chloride resistant tanks to store one or more carloads. *Ten thousand gallons should be the minimum storage capacity for plants using tank cars of ferric chloride.* Wood, reinforced concrete, or steel tanks lined with rubber with all exposed exterior surfaces painted with a ferric chloride resistant paint are the ideal containers. Covered tanks need not be sheltered but, in the case of unsheltered tanks, the strong liquor received during warm weather should be diluted in the storage tanks during the colder months to prevent crystallization. If possible, storage tanks should be elevated to permit the liquor to flow by gravity to dilution tanks or feeders, thereby confining all pumping to the simple air lift unloading operation from the car.

The concentrated ferric chloride solution taken from storage is preferably diluted to a 2 or 3 per cent solution when applied by one of the methods noted later in this article under "Feeding Equipment." Rubber-lined wood tanks under cover serve the Sewage Treatment Works of Milwaukee.

Crystal Ferric Chloride

Crystal ferric chloride is the oldest commercial form. As indicated in the accompanying graph, four hydrated crystals of ferric chloride can be formed; but, only the dodecahydrate, $Fe_2Cl_6.12H_2O$, (commonly written $FeCl_3.6H_2O$) is now commercially available. This material contains 60 per cent $FeCl_3$ by weight, is in the form of large yellow or brown lumps, has a melting point of 98.6° F., is slowly soluble in water at average tap temperatures, and is moderately hygroscopic.

The crystals are marketed in non-returnable, hardwood, paraffine-lined barrels of 55 gallons' capacity, which contain approximately 435 pounds of material. To prevent melting, and possible leakage, it is advisable to store barrels in single tiers under dry conditions at temperatures below 98.6° F. *The storage space required is approximately 70 square feet per ton of $FeCl_3$.*

Equipment for preparation of solutions and feeding crystal ferric chloride will be discussed in connection with anhydrous ferric chloride solutions, because of the close similarity of each.

Anhydrous Ferric Chloride

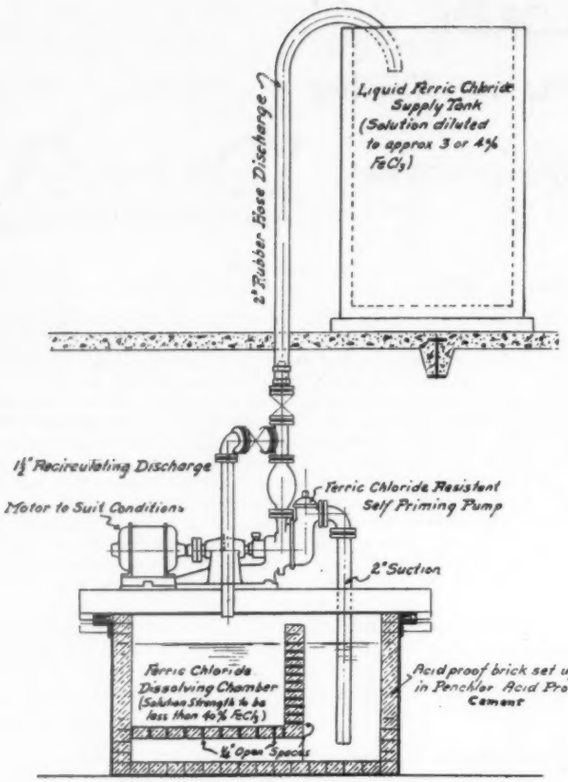
Anhydrous ferric chloride occurs rarely in nature, possibly the only source being the lava of Vesuvius. It takes the form of small greenish-black crystals with a melting point of 577.4° F., and is extremely hygroscopic, being readily soluble in water to 45 per cent concentrations at room temperatures above 55 degrees. The solubility curve for crystal ferric-chloride applies also to the anhydrous salt.

At present, the anhydrous form is being shipped in non-returnable steel drums holding 150 pounds of material. The drums, 15½ inches in diameter by 20 in height and weighing 10 pounds, are fitted with a 9-inch air-tight gasket and lid held in place by 4 screw bolts. These drums are convenient packages which may be stacked and stored indefinitely without deterioration. *Storage space required is approximately 40 cubic feet per ton of $FeCl_3$.*

Anhydrous ferric chloride has a decided advantage over the other forms by reducing transportation costs and storage space requirements 40 per cent or more. In addition, waste by leakage or deterioration is eliminated.

Preparation of Solution, Feed Methods And Equipment

The hygroscopic character of ferric chloride prohibits the use of dry feeds. The corrosive nature of solutions prevents the use


Liquid Ferric Chloride Supply Tank (Solution diluted to approx 3 or 4% FeCl3)
2" Rubber Hose Discharge
1½" Recirculating Discharge
Motor to Suit Conditions
Ferric Chloride Resistant Self Priming Pump
2" Suction
Ferric Chloride Dissolving Chamber (Solution Strength to be less than 40% FeCl3)
Acid proof brick set up in Penchlor Acid Proof Cement
½" Open Spaces

TYPICAL ARRANGEMENT of ANHYDROUS FERRIC CHLORIDE MIXING AND PUMPING UNIT

Sketch of Trouble Free Equipment and Method of Dissolving, Diluting and Feeding Ferric Chloride.

of ordinary piping and feeding equipment. A 20 per cent ferric chloride solution rapidly attacks the common metals and dehydrates wood, causing it to warp and shrink. Wood, or reinforced concrete, resists the action of weak solutions since excessive hydrolysis forms a protective hydrate coating. Equipment made of, or lined with, rubber, glass, Bakelite, or ceramic material, or the resistant metals such as Durichlor, or Hastelloy "C," will resist all concentrations of ferric chloride at normal temperatures. Rubber, glass, or ceramic materials may require additional protection against mechanical abrasion, or heat variation.

Feeding apparatus may vary from a simple solution tank with constant head orifice box to a modern "electric eye" controlled installation such as that used at the Chicago Sanitary District. The ideal and foolproof method of feeding involves 3 distinct steps: (1) Solution, (2) Dilution, (3) Application.

Dissolving Tanks

Solution tanks are necessary for dissolving either the crystal or anhydrous ferric chloride. Concentrations of less than 40 per cent are recommended to prevent crystallization and, in the case of anhydrous ferric chloride, high temperatures at the time of preparing the strong solution.

Solution strengths should be determined by adding a weighed quantity of ferric chloride to a definite volume of water as hydrometer measurements have proved to be unreliable. The tank should be at least partly filled with water before adding anhydrous ferric chloride to prevent the formation of the slowly soluble higher crystals and if the total contents of a drum are not added at one time the lid should be tightly replaced. Solution tanks of steel, reinforced concrete, or wood, lined with rubber and faced with acid-proof brick and cement, and of sufficient size to dissolve a 12 hour supply of ferric chloride, are preferable. A material rack, or compartment, and mechanical means of agitation are desirable features. Here illustrated is such a tank in connection with a pump which serves the dual purpose of agitating and lifting the concentrated liquor to the dilution tank above. The solution may be raised to the dilution tank by a vacuum lift if prepared.

Dilution Tanks

Dilution tanks are advisable for preparing and supplying uniform solutions to feeders. Concentrated solutions are diluted to 3 or 4 per cent $FeCl_3$ by adding gauged volumes of water and liquor. Experience indicates that stronger than 5 per cent solutions exhibit intense localized reaction on application and solutions weaker than 2 per cent may be appreciably hydrolyzed, especially by diluting waters of high alkalinity. Dilution tanks may be similar in construction to solution tanks without the acid-proof brick facing. Reinforced concrete tanks painted with a ferric chloride resistant paint, or large stoneware crocks are suitable. Other desirable features would include a mechanical stirrer, a graduated gauge rod, or glass, and a capacity for at least 4 hours' supply of solution. A tank with the depth exceeding other dimensions is preferable for more accurate gauging.

Solution Feeder

A positive displacement or a variable siphon head type of solution feeder is recommended for applying ferric chloride solutions. Several such corrosion resistant feeders, which have entirely corrected the uncertain performance peculiar to the old orifice type feeder, are on the market today. These feeders may be either manually or automatically regulated. Space does not permit even a limited discussion of all such feeders but following is a list of manufacturers: Galigher Company, Salt Lake City, Utah; Hills-McCanna Co., Chicago; Omega Machine Co., Kansas City, Mo.; Phipps & Bird, Inc., Richmond, Va.; Proportioneers, Inc., Providence, R. I.; Wallace & Tiernan, Inc., Newark, N. J.

Obviously, a gravity flow from solution tank to the final point of application is the ideal feeding arrangement. When lifting is necessary, any method which employs ferric chloride resistant materials may be used. Rubber-lined or hard rubber pumps, pipe and fittings are satisfactory for handling ferric chloride solutions at normal temperatures. Equipment made of Durichlor, or Hastelloy "C" is recommended for hot solutions.

For simple coagulation of sewages with ferric chloride, water purification practice for flocculation and sedimentation will give the best results. For sludge conditioning rapid agitation for 5 or 6 minutes followed by continuous filtration is preferable to the batch method.

Ferric Chloride Service Tank—Rubber Lined. Note Hose Connections and Hills-McCanna Co.'s "Saunders" Pinch-type Diaphragm Valves for Corrosive Liquids

SLUDGE INCINERATION

A Review of Modern Developments and the Status of the Practice

By E. T. KILLAM

Consulting Engr., New York, N. Y.

Developments in treatment plant equipment during recent years have demonstrated the feasibility of treating sewage essentially without nuisance—in, or adjacent to, closely built up areas. The economic advantages of elimination of long interceptors, and the prevention of deterioration of sewage quality prior to treatment by reducing detention time in interceptors, frequently establishes the desirability of constructing plants relatively close to centers of population instead of at remote locations, essential with some of the older types of plants. The increased importance of satisfactory sludge handling under such conditions has, among other factors, stimulated interest in sludge destruction by burning.

Methods of Sludge Drying and Incineration

Methods of drying and incineration of sewage sludge may be summarized as follows:

(A) Drying (For Fertilizer)

- (1) Without Preliminary Dewatering
  - (a) By Spray Dryer, such as at Plainfield, N. J.
- (2) With Preliminary Dewatering on Sand Drying Beds
  - (a) By Rotary Dryers at Grand Rapids, Mich., and Dayton, Ohio
- (3) With Preliminary Dewatering on Vacuum Filters
  - (a) By Rotary Dryers at Milwaukee, Wis.; Pasadena, Calif.; Houston, Texas

(B) Complete Incineration

- (1) After Dewatering on Sand Beds
  - (a) By Incineration in garbage-rubbish type incinerator of conventional design, contemplated or tried at a few plants with no known case of routine operation
- (2) After Dewatering on Vacuum Filters
  - (a) By Multiple Hearth Type Units for drying and incineration in one-step
  - (b) By Flash Dryer and Pulverized Fuel Type Incinerators, including drying followed by optional incineration

(C) Complete Incineration of Screenings

- (1) After Partial Dewatering in Roll Press
  - (a) In Hand Stoked Modified Garbage and Rubbish Type Incinerators, at Los Angeles "Hyperion" plant since 1934, and at Westchester County Sanitary District Plants since 1930
- (2) After Partial Dewatering in Centrifugal Machines
  - (a) At Milwaukee in hand stoked modified garbage and rubbish type incinerators
  - (b) At Milwaukee and Niagara Falls in multiple hearth type mechanically stoked—since 1937.

In addition to the foregoing applications of drying and incineration of sewage sludge and screenings, equipment now available offers a variety of special combinations deserving consideration in certain cases, and depending upon local conditions. Of particular interest are the possibilities in the combined disposal by incineration of garbage, rubbish, and sewage solids.

It is well recognized that the properly designed and well operated garbage and rubbish incinerator of today, will, under normal conditions, produce a substantial volume of excess heat.

There are notable examples of effective utilization of waste heat from garbage incineration in producing steam and power. The production of power, however, creates certain demands which must be considered in design and operation, and economical power production will for some time be limited to plants of substantial size.

An alternate use of such excess heat from garbage incineration (namely, as a means to drive off sufficient moisture from the sewage solids to make the sludge combustible without purchased auxiliary fuel) affords an interesting application of combined disposal.

Incineration and drying of sewage solids has doubtless been retarded due to the recognized item of operating cost, for driving off the moisture in the upper range of moisture content. If heat which would otherwise go up the incinerator stack may be utilized for this purpose, a consequent substantial reduction in operating cost is effected. This saving, combined with other obvious advantages, in many locations, of constructing the sewage disposal and garbage incineration plants at a common site, should make combined wastes incineration worthy of consideration in numerous instances, and the scope of applicability of incineration of sludge will, thereby, be substantially widened.

Inasmuch as the recent installations have been of the multiple hearth type, or the flash dryer and incineration type, these methods will be further discussed in brief.

Multiple Hearth Type Incineration

In 1934 the multiple hearth type incinerator, developed in the mining industry for roasting copper ore, was first applied to the incineration of sewage sludge at Dearborn, Michigan. In this, as in later installations, sludge is partially dewatered on vacuum filters prior to incineration.

The multiple hearth incinerator consists of a refractory lined circular steel jacketed unit, with as many hearths as may be indicated for the specific installation. Rotating plows on each hearth, driven by a vertical hollow air-cooled central shaft, constantly agitate and plow the material during drying and burning. The material drops through staggered openings in each hearth, to the next hearth below, being finally discharged from the bottom hearth in the form of an inert ash.

Multiple hearth installations normally include a blower for producing a supply of cooling air for the hollow shaft and revolving arms, a motor for driving the rabble arms, a rotating motor driven feeder, oil burner installation, and temperature control equipment.

In several cases preheaters have been included in the layout. The economic justification for a preheater, by means of which waste gases are utilized to heat the air supply to approximately 900 degrees F., depends upon the plant size, contemplated daily duration of operating period, and character and moisture of sludge to be burned.

The planned range of temperature at the furnace exit is approximately 1100 to 1300 degrees F. under normal optimum operating conditions.

Beginning with the notable pioneering installation at Dearborn, Michigan, in 1934, numerous installations of the multiple hearth type incinerator have been undertaken. Recent reports indicate that equipment of this type has been, or is being installed, in 21 or more plants at this writing.

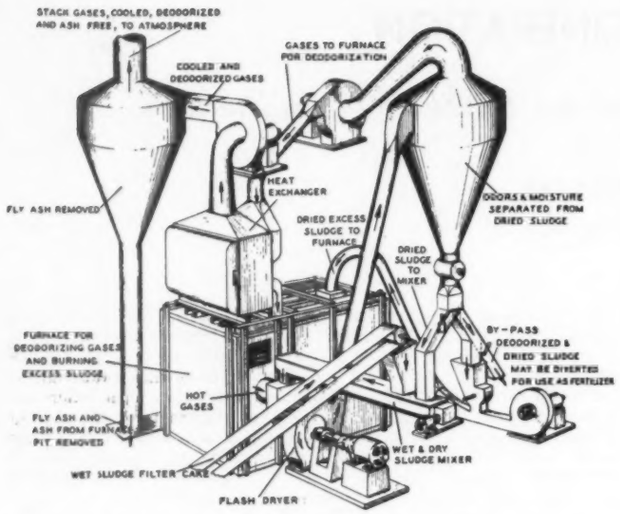
Installations at various plants to date vary in size from a single 9 ft. 3 in. diameter unit of four hearths, to the largest installation at Detroit, where four 22 ft. 3 in. diameter, 12-hearth units have been installed. It thus appears that America's largest Multiple Hearth Furnace installation is approximately seventy times the size of the smallest installation.

The original Dearborn incinerator handles mixed raw chemical and digested Imhoff sludge, the quality of which is indicated by the fact that the long term average volatile content of the cake fed to the incinerator was 46.6 per cent.

Subsequent installations have been in plants which will produce sludge of widely varying characteristics, including the following:

- (a) Raw Primary
- (b) Raw Chemical
- (c) Digested Primary
- (d) Raw Activated
- (e) Digested Activated

Several units have been purchased for incineration of fine screenings and 5 units have been installed with the expressed intention of handling ground garbage along with the sludge.


STACK GASES, COOLED, DEODORIZED AND ASH FREE, TO ATMOSPHERE
GASES TO FURNACE FOR DEODORIZATION
COOLED AND DEODORIZED GASES
HEAT EXCHANGER
FLY ASH REMOVED
ODORS & MOISTURE SEPARATED FROM DRIED SLUDGE
DRIED EXCESS SLUDGE TO FURNACE
DRIED SLUDGE TO MIXER
FURNACE FOR DEODORIZING GASES AND BURNING EXCESS SLUDGE
BY-PASS DEODORIZED & DRIED SLUDGE MAY BE DIVERTED FOR USE AS FERTILIZER
HOT GASES
FLY ASH AND ASH FROM FURNACE PIT REMOVED
WET & DRY SLUDGE MIXER
WET SLUDGE FILTER CAKE
FLASH DRYER

The C. E. Raymond System of Flash Drying and Incineration. (This System Makes Permissible Complete Sludge Incineration or a Partial Diversion for Use as Fertilizer. Another Illustration Shows the Cyclone End of the Raymond System in Service.)

Flash Drying and Incineration

Flash drying and incineration of sewage sludge was first undertaken on a large scale at the West Side Plant of The Chicago Sanitary District in 1933.

This type of equipment involves incineration in two stages—or in other words the drying of the solids to approximately 10 per cent moisture, followed by incineration of the dried material.

The filter cake, with a normal moisture of 75 to 85 per cent, is mechanically mixed with sufficient dried material to develop proper consistency for drying in the flash dryer. Hot gases and this mixture drop into the flash dryer, are violently agitated, and the dried material and vapors are discharged into a cyclone collector. The dried material—approximately 10 per cent moisture—is mechanically divided, a portion being returned to the mixer for blending with the wet filter cake. The balance, or excess, is sent to storage for fertilizer or to a pulverized fuel type of incinerator for destruction, as the case demands. The vent vapors are likewise discharged to the incinerator.

The average design temperature in the dryer is 1100 to 1300 deg. F., and the temperature of the vent vapors varies from approximately 200 to 300 degrees.

The initial installation—at Chicago's West Side Plant, was designed to dry and incinerate raw activated sludge filter cake at 80 to 85 per cent moisture. The rated capacity is 2,000 pounds net dry solids per hour or 8,000 pounds of water evaporation per hour.

Basing the design upon the performance of this unit, equipment was installed at the Calumet Plant of the Chicago Sanitary District and placed in operation in 1935. Three units—each with a capacity of 6,000 pounds net dry solids per hour, or 24,000 pounds of water evaporation per hour, were included. The sludge handled consisted of raw activated filter cake—with small amounts of grit and heavy primary solids from 20 minute detention primary tanks.

In November, 1937, this same type of equipment was placed in service at Neenah-Menasha, Wisconsin, with a capacity of 0.75 tons dry solids per hour, or 3,500 pounds of water evaporation per hour. The sludge at this plant will at times be digested—primary sludge, and at other times will be chemical sludge. A large proportion of paper mill wastes—with high clay content, has at times developed sludge as low as 35 per cent in volatile content.

Similar equipment is now being installed at Buffalo, New York, for incineration of partially digested primary sludge. This plant includes three units each, with a capacity of 5,000 pounds per hour evaporation.

The largest installation of flash drying equipment is in Chicago's notable South West Activated Sludge Plant, where four units—each served by two drying units, with the latter having an evaporation capacity of 20,000 pounds each per hour, are being installed. In this installation power will be generated from combustion of the pulverant dried sludge, with the assistance of auxiliary powdered coal. In this single plant with a total evaporation capacity of 40 tons per hour, combustion engineering has attained a real goal in sewerage practice in America.

The first installation under contract locally, is at Tenafly, N. J., where a small single unit of the drying apparatus, with an evaporation capacity of approximately 0.35 tons per hour, is to be installed, for drying raw activated sludge filter cake and fine screenings, preparatory to the burning of the dried material with garbage and rubbish in open hearth incinerator of conventional design.

Summary

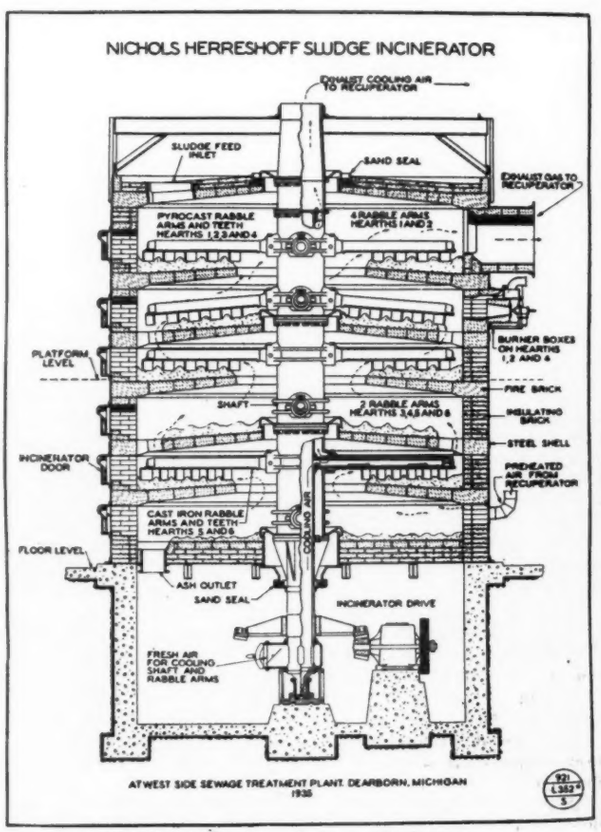
In summary, sludge disposal by drying or incineration has constituted one of the most active phases of development, in the past few years, in the field of sewage treatment.

While operating data and operating costs for a variety of installations will soon be available, it can be safely stated that careful consideration of the local conditions in each municipality will be necessary in order to approach the most economical solution of the problem.

The variables affecting alternate methods of sludge disposal vary no less than the wide range of requirements for degree of sewage treatment. In this way, it would appear that a careful analysis of the problem prior to final selection of the method of sludge disposal, will necessitate thorough consideration of the variables involved.

The characteristics of the sludge and moisture and combustibles content vary widely, depending upon the type of treatment from which the sludge originates. The volatile content of various sludges may vary to as wide a range as from 30 per cent of the total dry solids, to 80 per cent, or even higher. While a heat value of 10,000 B.t.u. per pound of dry volatile matter has frequently been used in computation, additional experience indicates wide variations in B.t.u. content per pound of combustibles.

The demonstrated performance in sludge incineration during the past few years, however, has placed this much needed facility in an important position as a method of sludge disposal. The above variables mentioned will not, it is believed, be of sufficient importance to jeopardize the success of the method, but will affect merely the economic advantages of one method or type of incinerator over another, where incineration is indicated as the preferred method.


NICHOLS HERRESHOFF SLUDGE INCINERATOR
EXHAUST COOLING AIR TO RECUPERATOR
SLUDGE FEED INLET
SAND SEAL
EXHAUST GAS TO RECUPERATOR
PYROCAST RABBLE ARMS AND TEETH HEARTHS 1,3,5 AND 7
4 RABBLE ARMS HEARTHS 1 AND 2
BURNER BOXES ON HEARTHS 1, 3 AND 4
PLATFORM LEVEL
FIRE BRICK
SHAFT
2 RABBLE ARMS HEARTHS 3,4,5 AND 6
INSULATING BRICK
STEEL SHELL
INCINERATOR DOOR
PREHEATED AIR FROM RECUPERATOR
COOLING AIR
CAST IRON RABBLE ARMS AND TEETH HEARTHS 3 AND 5
FLOOR LEVEL
ASH OUTLET SAND SEAL
INCINERATOR DRIVE
FRESH AIR FOR COOLING SHAFT AND RABBLE ARMS
AT WEST SIDE SEWAGE TREATMENT PLANT, DEARBORN, MICHIGAN 1935

The Multiple Hearth Dryer-Incinerator

NICHOLS ENGINEERING & RESEARCH CORP.

60 WALL TOWER
NEW YORK, N. Y.

NERCO

UNIVERSITY TOWER
MONTREAL, P. Q.

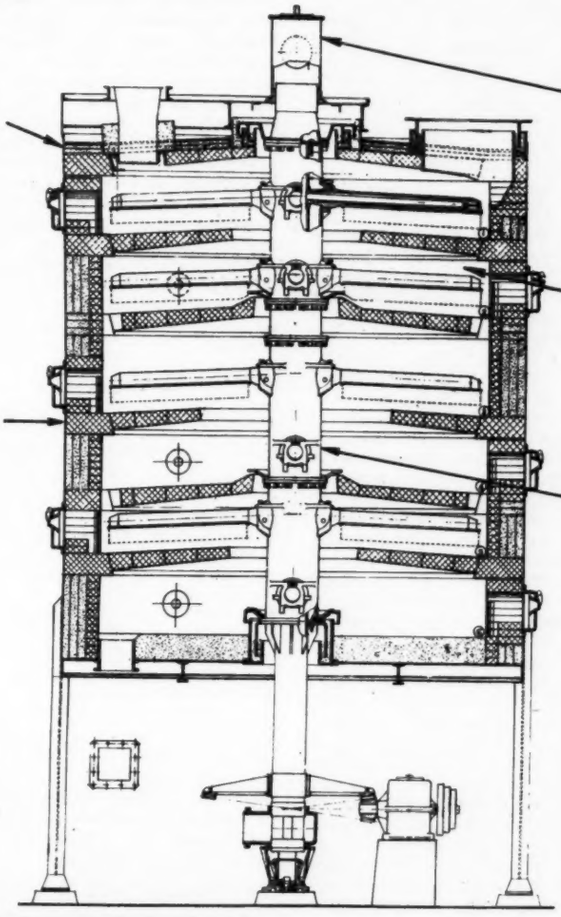
COMPLETE DISPOSAL BY INCINERATION

- ★ INCINERATION OF SEWAGE SLUDGE FILTER CAKE.
- ★ INCINERATION OF THICKENED LIQUID SEWAGE SLUDGE.
- ★ INCINERATION OF GROUND GARBAGE.
- ★ INCINERATION OF FILTER CAKE OR LIQUID SLUDGE WITH GROUND GARBAGE.
- ★ SLUDGE DRYING.

Complete incineration or drying takes place in one self-contained, fully automatic unit: requires minimum attention from operator.

High thermal efficiency: minimum radiation ensured by operation in one heavily insulated unit.

Over 25 cities are now using Nichols Herreshoff Equipment. Capacities range from 3 to over 1,200 tons wet feed per day.

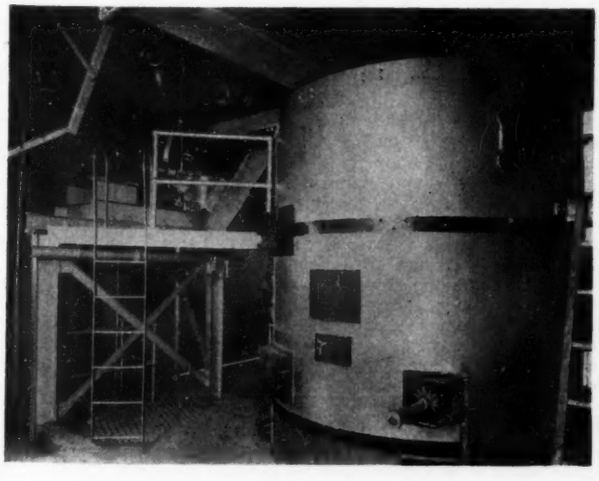


Central shaft and rabble arms preheat air for combustion.

All gases deodorized at high temperature within the incinerator.

Slow moving incinerator parts ensure minimum maintenance. No abrasive materials carried through fans or ductwork.

Low power consumption, only 2 motors of low rating required for incinerator.



WHITE FOR BULETIN NO. 210, illustrating and describing the many advantages of Nichols Herreshoff Incinerators.

Nichols Refuse Incinerators of advanced design are available for problems involving the disposal of municipal trash and garbage.

SIMPLIFICATION OF SEWAGE PLANT DESIGN.

Raw sludge to inert ash by incineration.

Combined incineration of sludge and garbage means only:

One capital investment.
One operating staff.
One incinerator to maintain.

At Left: View of Nichols Herreshoff Incinerator at Ashland, Ohio. Undigested liquid sludge, resulting from primary sedimentation and trickling filters is incinerated separately or together with ground garbage. Garbage grinder is seen at left; incinerator at right.

· SEWAGE AND EFFLUENT ANALYSES

The Significance and Interpretation of Results

By DR. RICHARD POMEROY, Research Chemist
Los Angeles County Sanitation Districts
Los Angeles, Calif.

MANY operating problems have been solved by laboratory tests, and those plants which have some laboratory control are usually better operated than similar plants where laboratory tests are not made. Increasing complexity of sewage treatment processes will cause the laboratory tests to be of added importance in the years ahead, and improvement of analytical methods will justify more confidence in the results of such tests.

Criticism of laboratory tests from the standpoint of the operator is chiefly due to four faults. The discussion which follows is designed to enable operators to avoid some of these faults, and to appreciate the proper significance of laboratory tests:

1. Erroneous results due to improper sampling.
2. Erroneous results due to improper test technique.
3. Unwise selection of tests.
4. Needless routine repetition of tests of little value.

The Sampling Problem

In order to avoid erroneous results, it is of course necessary that the operator learn how to carry out the laboratory procedures. The most important cause of error, however, is not in the laboratory procedure, but is in faulty sampling. *Much time may be wasted in making careful laboratory analyses on samples which fail to correspond to the materials which they are supposed to represent.*

(1)—Crude Sewage

Proper sampling of sewage influent to a treatment plant is difficult. Sewage varies in quality as well as quantity from hour to hour, and a single grab sample of raw sewage cannot be expected to give much information as to the average strength of the sewage throughout the day. Representative samples can be obtained only by compositing sub-samples taken at least hourly. The sub-samples must be *composited in proportion to the flow.* In plants where no one is in attendance at night, a few special samples should be taken of the sewage during the night, and from the test results a correction worked out which can be applied to the results obtained on daytime composites, to give approximate 24-hour averages.

Sampling of raw sewage is further complicated by the coarseness of part of the suspended matter, and by the lack of uniformity of the sewage in various parts of a flow channel. This is of no importance for tests depending upon soluble matter, such as the alkalinity test, pH, etc., but for determinations of suspended solids, settleable solids, turbidity, and B.O.D., care must be exercised to secure a representative proportion of solids.

When sewage is flowing at moderate velocity through a sewer or other channel, the heavier solids are rolled along and concentrated near the bottom. Samples from such channels will at best be only approximations of true samples. If the sewage passes through pumps, comminutors, flocculators, or channels where there is agitation, satisfactory samples may be more likely secured at such places.

(2)—Effluents

The sampling of treatment plant effluents is less difficult than the sampling of raw sewage. Coarse material has been removed and in the case of effluents of trickling filter and activated sludge plants, hour to hour variations are smaller than with the raw sewage. Sub-samples for composites may be taken at 2-hour intervals instead of hourly. Bear in mind that the daytime samples may give an entirely false picture of the average condition of the effluent. Much of the effluent which leaves the plant during the early part of the day may have been weak night sewage, and may have undergone prolonged treatment, so that it will be much lower in B.O.D. than the effluent leaving the plant during the evening hours. A few tests on samples taken around the clock will give a satisfactory indication of the strength of the effluent where routine sampling is possible only during part of the day.

Sample Preservation

All sewage and effluent samples should be preserved by icing in order to protect against bacterial changes in the sample bottle.*

[*In this matter the reader should examine a valuable article by Hatfield and Phillips, "The Preservation of Sewage Samples," which is to appear in an early issue following this one.—Ed.]

(3)—Sludges

The sampling of primary sludge for measurement of the solids (or moisture) content is very difficult. Sub-samples must be drawn almost minute by minute when sludge is being pumped if a representative composite is to be secured. This is rarely practical. Solids determinations on raw sludges, when made on grab samples, are seldom representative. Determinations of the percentage of organic matter in the sludge solids (or per cent volatile) in contrast to the solids determinations, are generally satisfactory if any reasonable care is used in sampling.

Activated and digested sludges are usually more uniform than primary sludge, and significant samples for moisture content may be secured with ordinary care.

No set of rules can be laid down for sampling at a sewage treatment plant. Each situation will have its own peculiarities and its own requirements. The operator must be aware of the importance and the difficulties of securing representative samples. It is far better to take *a few reliable samples* than to spend much time analyzing samples which are not representative.

Tests

(Routine and Special)

To avoid the faults of poorly chosen tests, and of wasted time on routine tests which are of slight value, the operator must know the purposes and significance of the various tests which he may choose for his own testing routine. Such knowledge will also enable him intelligently to read and discuss the results reported from other plants.

Every plant should have a schedule of routine tests, and a repertoire of tests for use in special investigations. This schedule may include nothing more than visual observations, or it may require the services of a full-time chemist. It should include only tests which have a definite purpose. The purpose may be to gain information useful in operation of the plant; it may be to ascertain if the quality of the effluent is of suitable purity for ultimate disposal; it may be to assist in future design; or it may be to demonstrate to the city, district, or state authorities the accomplishments of the plant. But it never should be to fill blank spaces on sheets which will never again be used. The schedule should be flexible. If a test has been made routinely for some time, and is ceasing to show enough new information to be of definite value, then it should be taken less often, or dropped altogether, or replaced by another test.

Following are the tests which may serve useful purposes in sewage treatment plants:

(1)—Physical Tests

Appearance and Odor: These are not laboratory tests at all, but they may be made easily and often tell so much that they should always be present in the operator's report. If the sewage presents no unusual appearance, then the operator should make the practice of recording the word "normal," or some equivalent. If he does this he will not forget to record the unusual conditions when they appear. The appearance frequently gives clues to industrial wastes, and may also indicate the condition of the sewage as regards septicity. "Odors" should include mention of hydrogen sulfide and any other odors likely to cause complaints. Also, odors of gasoline or dry-cleaning solvents should be particularly observed, as vapors of these materials in the sewers constitute a serious explosion hazard and should be eliminated.

Temperature: The operator should know the temperature of his sewage, even though he can't do anything about it. The information may be of value to the engineer or consultant. Routine temperature tests are not necessary; occasional tests taken regularly during the various seasons are sufficient to give the temperature history.

(2)—pH, Alkalinity, Chlorides

Determination of the pH values of sewage entering a treatment plant is properly recommended as a routine test in most

situations. It provides information which may be useful in explaining variations in plant behaviour, and is valuable in detecting industrial wastes.

Alkalinity titrations may also be useful in locating industrial wastes and it provides a quantitative measure of the capacity of the sewage to receive acid wastes. Occasional alkalinity measurements are of value in many places, but the test is rarely of sufficient importance to be made a matter of routine.

Chloride determinations have proved of value in special situations, as for example in measurements of salt water infiltration and in tracing industrial wastes.

(3)—Measures of Sewage "Condition"

Sulfides. The measurement of sulfides in sewage is in many places a matter of great importance. In the majority of cities of California sulfides in the sewage are either a threat or a serious problem. In such places regular tests should be made for sulfides in the sewage reaching the treatment plant, or at various locations on the sewer system, to detect points at which septic action becomes of moment. Even a half part per million of dissolved volatile sulfides will cause odor nuisance, tarnishing of brass and paints, and slow disintegration of concrete in confined conditions. A record of sulfide tests will indicate whether the situation requires remedial measures. If some control measures must be taken, they may include: cleaning of the sewers, ventilation of the sewers, control of industrial wastes, treatment of sewage with metallic salts, or chlorination. Whatever control measures may be used, it is evident that regular sulfide tests are required as a measure of the adequacy of the control.

A distinction must be made in sulfide tests between total sulfides, dissolved sulfides, and hydrogen sulfide. Dissolved sulfides may be distinguished from the sulfides held in the suspended matter by removing the suspended matter with coagulants and analyzing the clear liquor. In ordinary sewage the concentration of total sulfides may be of the order of 0.5 p.p.m. before any appreciable concentration of dissolved sulfides will be present, but in sewage which has been treated with metallic salts for sulfide control the insoluble sulfides may have almost any value, since the purpose of the metallic salts is to convert dissolved sulfides to insoluble metal sulfides. Hydrogen sulfide, which is the direct cause of the trouble, is determined by calculation from the dissolved sulfides and the pH. [This method, developed by the author, is fully described on another page in this volume.—Ed.]

The detection of hydrogen sulfide in the atmosphere by the use of lead acetate paper is extremely simple and may be a valuable test. The paper darkens in the presence of traces of H_2S. The operator can estimate the seriousness of the condition by the rapidity of blackening. [For a simple method see "The Determination of Hydrogen Sulphide"—by George Martin, on another page in this volume.—Ed.]

Measures of sewage condition are concerned not only with septicity, as indicated by sulfides, but also with oxidized conditions attained by biological oxidation and by chlorination. Special tests for biologically oxidized effluents are discussed later under "Special Tests for Oxidization Plants."

Chlorine Residual. Determinations of chlorine residual are essential where chlorination is practiced. Ortho-tolidin is almost universally used for this purpose. All of the chlorine added to sewage in any ordinary case enters into combinations. Some of these combinations remove the chlorine completely from the field of action. Others hold the chlorine loosely, so that it may be released to react with other substances. The ortho-tolidin test also measures a part of this loosely-held chlorine. Less chlorine than is required to show a so-called residual may suffice to accomplish a high degree of sterilization, especially if the object is sulfide control, yet many microbes are not killed until the chlorine dosage is much higher than is required to show a residual. In the chlorination of crude and settled sewage the test must be looked upon as more qualitative than quantitative. The operator may distinguish between a "strong residual" and a "weak residual," but numerical values in parts per million are generally of little significance. In the case of well-clarified sewage effluent the results may have quantitative value. With these limitations properly emphasized, we must still recognize the test to be very important for chlorination control. Bacterial tests, later discussed, likewise serve to measure efficiency of chlorination.

Chlorine Demand tests are also useful in chlorination control. They show the amount of chlorine required to reach some arbitrary point, such as the starch-iodide end-point or the ortho-tolidin end-point. The test not only serves to determine chlorine requirements, but also may provide information as to the strength or the septicity of the sewage and may aid in evaluating the effect of industrial wastes.

(4)—Measures of Sewage "Concentration" and Plant Efficiency

Various tests have been devised to indicate the amount of pollution, or the "strength" or "concentration" of sewage or effluent. Since these tests may be used for comparisons of raw sewage and effluent, they may serve as measures of accomplishments of the plant.

Settleable Solids. A simple and reliable test of efficiency for for plain sedimentation installations is the settleable solids determination using Imhoff cones. If used as a matter of routine, this must be made on composited samples.

Turbidity. The turbidity test is especially useful in determining the relative degree of clarification of effluents, and may be made to give a good approximation of the suspended solids content.

Suspended Solids. A still more accurate test is the suspended solids determination, made by filtering through an asbestos or paper filter and weighing the solids collected. What has been said previously about the difficulties of sampling raw sewage must be recalled here; this difficulty frequently gives misleading results. Another source of error in this test arises from the fact that 5% to 10% of the suspended solids of sewage are so coarse that they must be rejected when a small sample is taken for filtering. Hence the result of the analysis is bound to be low even if the original sample is as representative as one can possibly hope for. Because of these errors suspended solids determinations cannot be used for more than approximate calculations of the weight of sludge expected to be removed by sedimentation.

Volatile Solids. The proportions of organic or "volatile" matter in the suspended solids is sometimes determined by igniting the filter and reweighing. This determination is too inaccurate and of too little interest in the case of ordinary sewage to be recommended for routine work.

Dissolved Solids. Dissolved solids determinations are of some interest in biological oxidation processes, because these processes remove some dissolved and colloidal matter. Total solids or dissolved solids determinations are necessary, if one wants information as to the solids removal in these processes. Because of the inherent inaccuracies of the test, one should not attach any significance to the day-to-day variations in the apparent dissolved solids removals; only averages of a week or a month are significant.

The B.O.D. Test. The most widely used measure of the degree of purification is the B.O.D. test. This test is of great value, but does not have the absolute significance sometimes attributed to it. The results may vary according to the sample dilution employed, the oxygen concentration, the type of microbes present, the nature of the diluting water, and even the brand of distilled water used for making synthetic diluting water. The test is true because certain commercial distilled waters contain significant impurities. It is desirable to set at least two dilutions on each sample. If the test is made with care, the results are valuable in revealing day-to-day variations in the efficiency of a plant, and in comparing similar plants. It should not be used as a sole criterion for comparing plants of different types, nor should it be used uncritically for testing industrial wastes.

Oxygen Consumed. The "oxygen consumed" test has been widely used in the past, and is still used in many places, especially in England. It is used to measure sewage or effluent concentration and has the advantage of yielding results quickly.

Organic Carbon. The determination of organic carbon has also been proposed as a measure of sewage strength. This test has not yet come into extensive use, although results are obtained in a few hours.

Ammonia and Organic Nitrogen may also be used to measure the relative concentrations of various sewages.

Chlorine Demand, as previously stated, is an index of sewage quality or strength. It is a simple, quick test to make.

(5)—Special Tests for Oxidation Plants

Relative Stability. This test is in part a measure of the pollution remaining in an effluent, and in part, a measure of the "condition" relative to the supply of oxygen. It is valuable as a comparative test if properly made, but the slightest air bubble in the bottle at any time during the incubation period invalidates the test. This source of error is common.

Dissolved Oxygen. In dissolved oxygen determinations, special care is required in sampling. Samples should be dipped from the final clarifier or secondary sedimentation tank, rather than from a flume or pipe after the effluent has tumbled over a weir, and they *must be put to test promptly after they are taken.* The

D.O. content of the effluent gives valuable information to aid the operator in control of the plant. In activated sludge process, throughout the plant it is the most valuable of all control tests, except possibly the determination of sludge percentages by settling in graduated cylinders. The activated sludge process cannot function satisfactorily when the tanks become devoid of oxygen. An oxygen content in the final clarifier of 1 to 2 p.p.m. is sufficient. If the oxygen content in the final clarifier rises above 4 p.p.m. the operator may cut down the air supply and thus conserve power. If the D.O. becomes too low, obviously the air supply should be increased. If the air supply cannot be increased, a deficiency of oxygen may be remedied by cutting down the circulating load of the activated sludge. It is better to have a low concentration of properly aerated sludge than to have a lot of semi-septic sludge. It often becomes desirable to measure the oxygen concentration at various points in the aeration tanks. When D.O. tests are made directly upon the mixed liquor of the aeration tanks, the result is only approximate, since the sludge consumes some oxygen after the chemicals are added. Such results are nevertheless valuable for control purposes.

Nitrites and Nitrates. Well-oxidized effluents, whether from activated sludge or trickling filters, contain nitrites and nitrates, and the concentration of the adequacy of the treatment.

Sludge Concentration and Density. Discussion of special tests for oxidation plants would not be complete without mention of the sludge concentration and density test, so important for control purposes in activated sludge plants. This test is made by settling the mixed liquor in one liter cylinders. The operator must bear in mind that this test does not show the true solids concentration, since there is great variation in the settling properties of different activated sludges. The actual sludge concentration can be determined only by measurements of suspended solids by weight. In activated sludge plants, dissolved oxygen determinations should always be used in conjunction with the sludge concentration tests.

(6)—Sludge Analyses

Solids Content (or Moisture Content). Sludge samples to be analyzed for solids content must be taken with great care, as mentioned previously. In the case of raw sludges, this test provides a basis for judging whether the sludge is being removed with a solids content as high as may be hoped for, and to determine the influence of variations in operation upon the concentration of the sludge. In the case of primary sludge, an average solids content of 4% is generally adequate, although concentrations as high as 6% or 8% may be obtained. Activated sludge with 2% solids is considered satisfactory. Long detention of digested sludge will allow concentration to 10%, but if the sludge is to be dried on sand beds or field, there is small advantage in concentrating it to more than 5% solids.

Per Cent Organic (or Per Cent Volatile). The principal use of the organic percentage determination on the sludges is for calculating the per cent destruction of the organic matter in the digestion process. The mineral matter in the sludge is practically enhanced in digestion, and hence the ratio of the organic matter to this mineral (ash) fraction of the sludge provides information on how much of the organic matter is converted to gas. Let us suppose that the raw sludge has 3 parts of organic matter to 1 part of ash (75% organic), and that after digestion it has 1½ parts of organic to 1 part of ash (60% organic); since 3 parts of organic have been reduced to 1½ parts, this represents 50% destruction of the organic matter, which may be considered to be satisfactory digestion. It must be borne in mind that the *actual* percentage organic in the digested sludge is not a measure of the digestion, since this fluctuates widely with variation in the composition of the new sludge. Rather, *it is the per cent reduction of organic matter that is significant.* In view of the large fluctuations which the composition of raw sludge is likely to show, it is evident that only long-time averages can be used for reliable calculations of the per cent disgestion.

A further use of the determination of organic percentage of digested sludge is in judging its fertilizer value, since the fertilizer value is roughly proportional to the organic content. The nitrogen content of the dry (digested) sludge is approximately 6% of the organic percentage. Thus, a sludge with 50% of organic matter may be expected to have about 3% of nitrogen.

pH Values. Determinations of the pH of digesting sludge are of use if the sludge is being treated with lime to start digestion. They may also be of value in diagnosing trouble when the sludge is foul smelling and appears to be digesting poorly. The test does not have any value for routine purposes in digestion tanks which are functioning normally, and its widespread use to judge the completeness of digestion is *not* warranted. Completeness of digestion is only one of several factors which may influence the pH, and even when other variables do not enter in, the pH is not sensitive enough to the progress of normal digestion to be of value. The true pH of the liquor of digesting sludge is rarely above 7.4 and probably never above 7.6, yet values of 7.8, and even higher are often reported.

[It is a fact that the carbon-dioxide contents of the digester gas is a more sensitive and dependable index of approaching conditions than the pH test can possibly reveal.—Ed.]

Volatile Acids. If one wishes analytical measures of the completeness of digestion which are more sensitive to short-time variations than is the per cent reduction of organic matter, then use may be made of the determination of volatile organic acids of ammonia in the sludge liquor, of the bicarbonate concentration, or of alkalinity of the liquor. Determination of the volatile acids is of the greatest value. In the early stages of digestion the acid concentration reaches high figures. Subsequently these acids are destroyed. When their concentration drops below 200 p.p.m. the sludge can be dried without odor nuisance or the breeding of flies regardless of the extent of digestion of other organic matter.

Ammonia concentration measures the extent of digestion of the proteins of the sludge.

Bicarbonate concentration in the sludge liquor is determined principally by the difference between the organic acids on the one hand and ammonia on the other. The bicarbonate in turn is the essential factor controlling the pH. The relative accuracy with which the bicarbonate concentration can be determined is a hundred times as great as the corresponding accuracy of the pH test, and the test is quite simple.

Alkalinity of the sludge liquor is even simpler to determine than the bicarbonate test, and gives almost the same result as the bicarbonate test, if the sludge is reasonably advanced in digestion.

In view of these facts, it is desirable for operators of small plants to make pH tests of the digesting sludge only when it is of foul odor and digesting poorly, and under other conditions to make occasional determinations of bicarbonate or alkalinity. In large plants it is desirable that occasional or routine tests be made for volatile acids, ammonia, and bicarbonate, and when this data is available the pH test of sludge can be abandoned entirely.

A frequent question is, "What is the relation of pH to foaming?" The answer is that, with one exception, there is no correlation known between pH and foaming. The exception is, when the acid content of the sludge is very high and the pH consequently low (below 6.8), and gas production is low, a subsequent acceleration of digestion will generally be accompanied by foaming. This is the condition usually experienced when a tank is placed in service without seed sludge. Foaming which occurs under other conditions apparently is not related to the pH, or to any other simple measure of the condition of the sludge liquor.

(7)—Bacterial Tests

Bacterial counts on raw sewage are enormous, and are very high on all effluents except those which are well clarified and then chlorinated. The bacterial tests are ordinarily made only on such effluents, or along streams or bodies of water into which effluents are discharged. The two commonest tests in this class are the so-called "total count" on agar plates, and the coli-aerogenes test. The first of these tests gives the total number of bacteria which are able to grow into colonies in plates of nutrient agar. The result does not represent the total number of bacteria in the sample, for the nutrient agar will support the growth of only a minor fraction of the innumerable species of bacteria which may be present. Furthermore, the agar plates give no information as to the presence of micro-organisms of the important class known as protozoa—animals of the microscope world. The test gives results, however, which are important for comparative purposes.

The coli-aerogenes test indicates the presence of bacteria of a certain group. These bacteria are found in enormous numbers in feces, and their presence in water indicates the probable presence of fecal contamination. Water showing these bacteria is considered unsafe—not because these bacteria are harmful but because their presence indicates that the water may also contain microbes of intestinal diseases, such as the typhoid bacteria and the dysentery amoeba. When a well-clarified effluent is chlorinated, the total bacteria counts may be reduced to relatively small numbers, and bacteria of the coli-aerogenes group may be virtually completely eliminated. Along with the coli-aerogenes group will go practically all of the pathogenic microbes.

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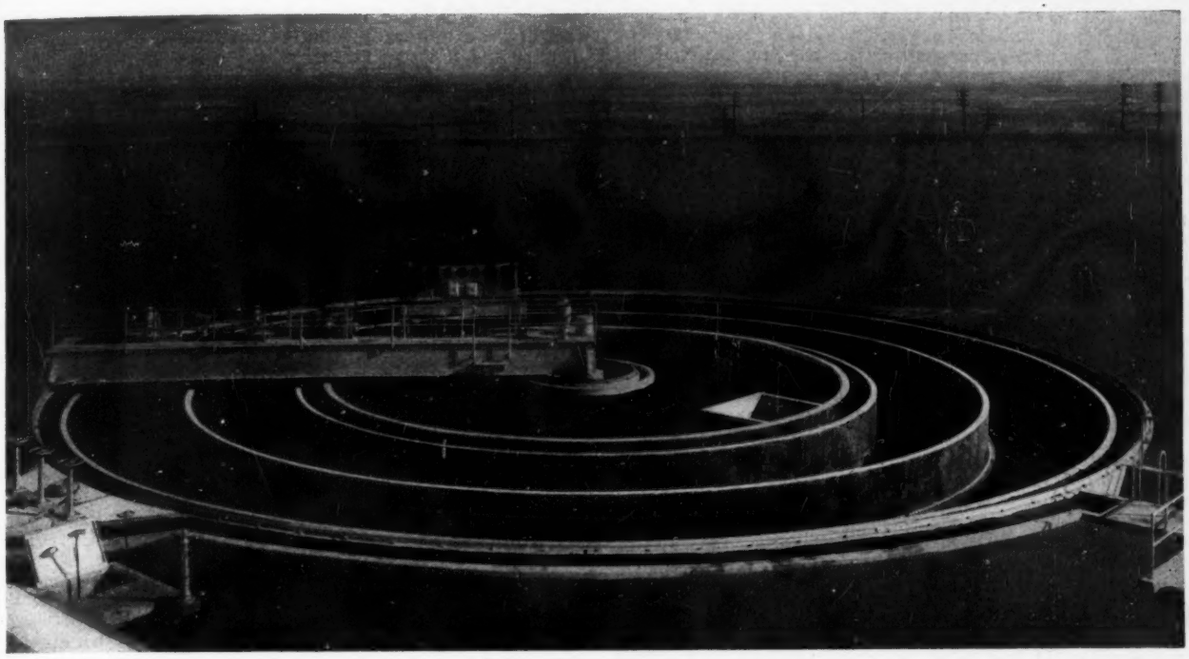

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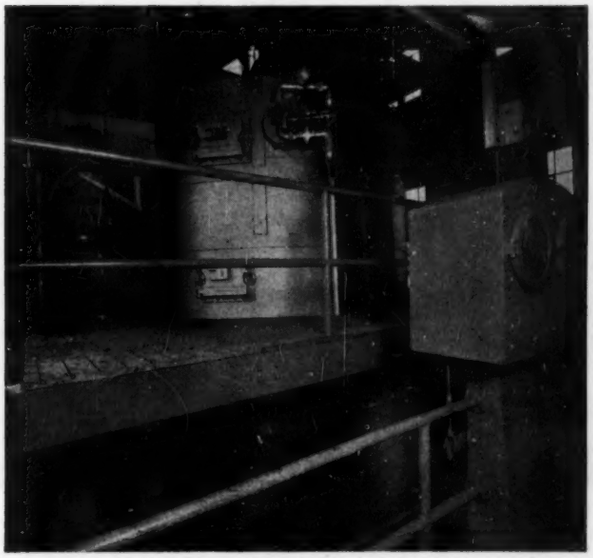

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FERTILIZER AND FERTILITY

Values of Sewage Sludge

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THE use of various types of sewage sludge as sub-grade fertilizer or soil builders has been advocated for many years. Enthusiasm to use this by-product of sewage treatment has come mainly from the layman, but soil technologists and soil scientists continue to wonder why sludge is not returned to the soil for its plant food and fertility value. (Note that a distinction is made between plant food content and fertility value.) Many farmers, gardeners, florists and green-keepers have tried the material, but frequently have stopped after some years.

Sanitary engineers in general have looked at the sludge problem as a question of destruction of noxious matters rather than conservation of values. Sewage plant operators have tried to stimulate its use. There is an increasing tendency to find ways and means to utilize sludge, principally as a fertilizer filler or for soil improvement through direct application.

An inquiry to determine why the material is not used on a larger scale, especially from smaller plants, or why the use has been discontinued, seems to indicate several reasons which can be summarized as follows: (1) insufficient knowledge of the value, (2) improper use of the material or insufficient preparation, (3) excessive claims made by the seller, or (4) lack of interest by the seller.

From a hygienic standpoint there is *no problem* if the sludge is used in a proper manner. A rather extensive inquiry made to determine whether ill-effects have been observed on animals or human beings, shows that where land disposal has been practiced for many years no disease or epidemics have occurred. This is probably due to the fact that users of large quantities of sludge have taken proper precautions. As a rule fresh sludge has been used only on forage crops and plowed under after application. Heat dried activated sludge and heat dried digested sludge appear to be safe for any reasonable use in agriculture, horticulture or floriculture, while well digested air dried sludge appears to be as safe as manures.

What Is the True Value of Sludge?

Determinations of the values in sewage sludges have chiefly been a matter of testing for the principal fertilizer ingredients (nitrogen, phosphorus and potash), while sometimes the organic matter content is taken into consideration. Users of sludge for agricultural or horticultural purposes have repeatedly called attention to the fact that the results obtained could not be entirely accounted for by the mineral or plant food constituents. The better results have been variously explained on the basis of: (1) the organic matter content of the sludge results in an increased moisture holding capacity of the soil, preventing retardation of growth or wilting during dry weather; (2) an improvement in the soil structure, especially in clay, allowing more air to enter and subsequently a stimulation of oxidation or organic matter by the soil organisms; (3) introduction of large numbers of bacteria and protozoa, resulting in a speeding up of decomposition, the introduction of micro-organisms, such as molds, into the soil, making the nutrients more available for the plants; (4) introduction of certain minerals needed for plant growth; absence of weed seeds, which may utilize the available plant food.

On the other side of the picture is the discontinuance of the use of sludge after several years on account of plant injury. The reasons advanced for plant injury have been mainly: introduction of poisons in the soil which were present in the sludge (certain industrial wastes); high grease content resulting in water logging and production of organic acids; burning of plants resulting from acidic decomposition products which make the soil acid.

Sludge Constituents—Major and Minor

Until a relatively short time ago it was assumed that only ten chemical elements (nitrogen, phosphorus, sulfur, calcium, magnesium, potassium, iron, carbon, hydrogen and oxygen) were indispensable for the growth of higher plants. Many other elements, if found effective, were regarded as plant stimulants. In 1914 Prof. Mazé at the Pasteur Institute in Paris, showed that other elements were necessary. Not much attention was paid until in 1923, when Miss Warrington at the Rothamsted Experiment Station in England found that boron was essential for beans and several other plants. Only during the last few years has it been found that a number of plants can not complete their growth cycle without minute quantities of boron, copper, zinc, manganese, possibly molybdenum and several others. These "minor," or "accessory," or "micro-nutrient" elements have a remarkable effect on various phases of plant growth. Iron, for instance, plays a role in oxidation, copper has been reported as

Preparation and Conditioning an Important Consideration in Marketing
Compare the handleability and saleableness of the lumpy product on the left as removed from the drying beds, and the uniformly granulated and aerated product turned out by a well known sludge disintegrator

essential in certain oxidase systems; manganese is essential to respiration and to nitrate reduction in plants; zinc may be important in the change of carbonic acid to water and CO_2; certain metal deficiencies produce chlorosis of varied types of green plants.

A compilation of the chemical composition of sludges, including the main fertilizer constituents and the "minor" elements, is given in Table I. For comparison it should be kept in mind that the average fertilizer ingredients of barnyard manures are about 2 per cent nitrogen, 1 per cent phosphorus (P_2O_5) and 1.5 per cent potash (K_2O). It is evident that in addition to the main fertilizer ingredients, small quantities of "minor" elements are present in the sludge which may play an important role in plant growth. The quantities of minor elements are relatively small, so that danger of poisoning the soil is absent. The quantities of lime salts present in the sludge varies with the hardness of the water supplies and the manner of sludge treatment. The amount of lime salts expressed as (CaO) may be as low as 2 per cent and as high as 12 per cent on a dry basis.

A Potato Crop—With and Without

From the same area, in a field side by side, potatoes on left were fertilized with 400 lbs./acre of Toledo's air-dried digested primary sludge, marketed under the name "Tol-e-Gro." The yield was just 200 per cent more than the pile on right not fertilized.

TABLE I

Average Chemical Constituents of Sewage Solids and Sludges*

Element	Fresh Solids	Digested Sludge	Activated Sludge
Total Nitrogen (N)	4.50*	2.25*	6.20*
Phosphoric (P_2O_5)	2.25	1.50	2.50
Potash (K_2O)	0.50	0.50	0.75
Silica (SiO_2)	13.80	27.60	8.50
Iron (Fe_2O_3)	3.20	6.00	7.20
Aluminum (Al_2O_3)	2.10	4.30	3.20
Calcium (CaO)	2.70	5.70	1.70
Magnesium (MgO)	0.60	1.00	1.40
Manganese (MnO)	0.02	0.04	0.03
Sodium (Na_2O)	0.80	1.50	1.00
Titanium (TiO_2)	0.06	0.10	0.08
Copper (CuO)	0.02	0.05	0.05
Barium (BaO)	0.05	0.10	0.06
Zinc (ZnO)	0.01	0.04	0.03
Lead (PbO)	0.10	0.20	0.20
Nickel (NiO)	...	...	0.005
Cobalt (CoO)	0.0002	...	0.0002
Sulfur (So_3)	1.2	2.5	2 90
Chlorides (Cl)	0.50	0.50	0.50
Chromium (Cr_2O_3)	...	...	0.20
Arsenic (As_2O_3)	trace	trace	0.013
Boron (Br_2O_3)	...	...	0.0115
Iodine (I)	...	...	0.001

*All figures being % of each ingredient on the dry basis.

Humus Value

As a soil builder the humus content of sludge is less than that of barn-yard manure, because the ash content is greater, but still is of considerable value in sandy and heavy clay soils.

The crude fiber (cellulose, lignin, etc.), being complex insoluble carbohydrates, resist bacterial decomposition and remain longer in the soil (TableII). Most of the so-called total organic matter gradually disappears, but is of importance from the standpoint of humus accumulation and moisture holding capacity of the soil. Soils which retain a higher moisture content, usually support a greater variety of plants and allow the plants to continue their growth even during dry spells.

Fats and greases are important chiefly because they make the sludge lump and interfere with the desirable uniform distribution of the sludge. Also, because grease decomposition produces acidic compounds, resulting in acidic soils. It is our experience that most of the injurious effects that may be chargeable to sludge application for a number of years are due to the accumulation of acids in the soil. The first few years these acids have a tendency to make insoluble plant foods present in the soil more available: hence, produce better results than might be expected from the sludge alone. After a few years the available insoluble plant food has been reduced and the soil becomes more and more acid. Certain plants, which desire a neutral or only slightly acidic soil, are retarded in their growth and finally are injured by the accumulated acidity. The simple application of agricultural lime (carbonate of lime) neutralizes this acidity. For best results in the long run, a judicious lime application every 3 or 4 years prevents a good deal of trouble. The fact that this simple remedy often has been overlooked accounts for reluctance of farmers and greenhouse growers to use sludge after a few years' trial.

Growth-Promoting Substances

Increasingly, it is recognized that plants do not synthesize vitamins or their precursors as a philanthropic act for the benefit of animal or man. These substances have a function in the plant itself. The substances are generally classified as growth-promoting substances, since they may induce root development, stem elongation, cell swelling, ripening of fruit, stimulate germination and flowering, and produce other responses. Farm yard manure and decaying vegetable matter have been shown to contain various growth-promoting substances. Tests made for the presence of some of these substances in sewage sludges are summarized in Table III.

The quantities of growth-promoting substances required to affect the growth of plants are extremely small. Comparatively large applications of artificially produced compounds may even cause injury or retardation. Indole and skatole derivatives appear to be among the most effective growth-promoting substances. Indole and skatole, as well as butyric, acetic and propionic acids, are produced during decomposition of sludge and can be expected to be present. The presence of various growth-promoting substances give to sludges a higher *fertility value* than indicated by a mere chemical analysis, which reveals only the principal *fertilizer ingredients.*

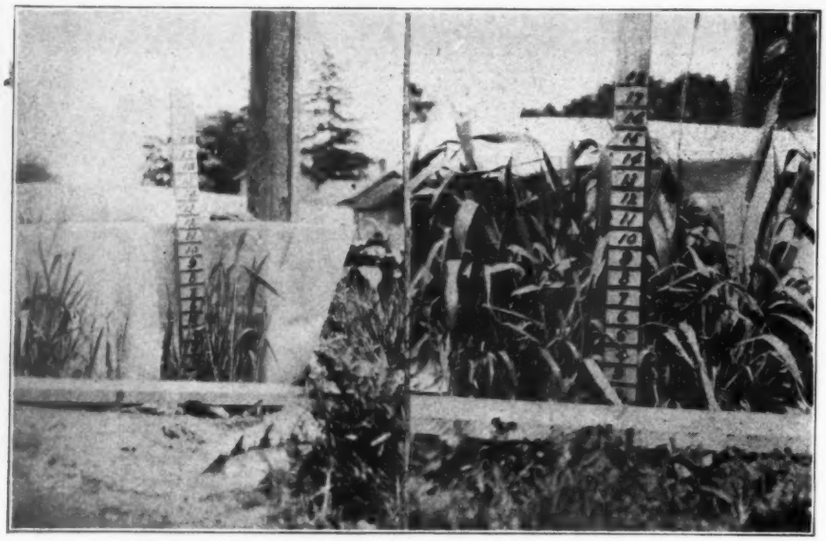
Practicing farmers have maintained for years that mineral fertilizers "burn out" the soil. What is meant is that mineral fertilizers stimulate the destruction of organic matter, making the plant food, plant stimulants and hormones available in greater abundance. This results in increased crop yields, but also gradually reduces the stored-up fertility of the soil. Thereby,

TABLE II

Composition of Sludges

Constituent*	Fresh Solids	Digested Sludge	Activated Sludge
Organic Matter	60-80*	45-60*	65-75*
Total Ash	20-40	40-55	25-38
Insoluble Ash	17-35	35-50	22-30
Pentosans	1.0	1.50	2.10
Grease and Fat (Ether)	7-35	3.5-17.0	5.0-12.0
Hemicelluloses	3 2	1.6	.....
Cellulose	3.8	0.6	7.0†
Lignin	5.8	8.4	.....
Protein	22-28	16-21	37.5

*All figures being % of each constituent on the dry basis.
†Includes lignin, etc.



A Small Grain Demonstration
In this instance, a 40-day growth of barley

TABLE III
Presence of Growth Promoting Substances in Sludges
(Relative Amounts of Single Substances)

Substance	Fresh Solids	Digested Sludge	Activated Sludge
Skatole, p.p.m.	1.2 -7.8	traces	none to traces
Indole, p.p.m.	0 12-7.0	0.5-1.0	0.0-0.05
Ascortic acid (Vitamin C)	++++	++++	++++
Carotene	+++	++	+
Tryptophane (free)	++++	+	++
(combined)	++++	++	+++
Tyrosine (free)	++++	+	++
(combined)	++++	++	+++
Phenyl compds.*	++++	++	++
Naphthyl compds.†	—	—	—

*As benzoic acid; † as ∝-naphthol.

the soil becomes poorer. The value of farmyard manure is in replenishing the organic matter, "minor" elements and growth-promoting substances. Its application is of importance, therefore, in making the soil gradually richer. A similar function can be ascribed to sewage sludge. Since sewage sludge contains only relatively small amounts of the principal fertilizer ingredients crop yield cannot be as great as from mineral fertilizers; but, like other improved animal manures, it improves the soil and will continue to do so if acidity is checked by lime applications.

Sludge Enrichment or Sludge Filler

The addition of mineral fertilizers to enrich sludge results in a more complete product. Not only are the necessary major plant foods present, but the required "minor" elements and growth-promoting substances are available. This combination produces a balanced fertilizer and, also, a soil builder. This balanced product gives higher crop yields without loss of soil fertility. Such a balanced product is of especial value for sandy and clay soils. The response of rich loamy or peaty soils to this balanced product should be less and it explains partly why experiments conducted with various crops in different soils may appear to be contradictory.

The amount of organic matter present is of importance, because of its favorable effect on the absorption capacity of the soil, and is of further interest because it is the carrier for organic nitrogen, which aids bacterial decomposition and becomes available to the plant when needed.

Crops and Plants Benefited

A compilation of plot experiment results and actual practice of crops and plants which have been benefited from sludge applications (Table IV) indicate that a number of grasses, root and leaf crops, trees and shrubs respond to sludge. The list is incomplete, because only those plants have been included where sludge was of *definite* value. Cases where the value was doubtful or contradictory have been disregarded. Sludge has been found to be of particular value on lawns and greens. It does not cause "burning," but small applications of lime are necessary from time to time.

TABLE IV
Crops and Plants Which Have Benefited from Sludge Applications

Field crops and fruits—
- Corn
- Wheat
- Rye
- Barley
- Turnips
- Grass
- Beets
- Mustard
- Potatoes
- Tobacco
- Cotton
- Apples
- Citrus fruits
- Strawberries

Flowers—
- Roses
- Carnations

(Many annual flowers respond to sludge, in some cases leaf growth is more stimulated than is flowering.)

Truck crops—
- Squash
- Tomatoes
- Turnips
- Pumpkins
- Beets
- Carrots
- Radishes
- Parsnips
- Onions
- String beans
- Lima beans
- Lettuce
- Spinach
- Sweet corn
- Cabbage
- (and others)

Trees and shrubs—
- Maple
- Ash
- Birch
- Chestnut
- Prunus
- Cornus
- Jasminium
- Hydrangea
- Berberis
- Spirea
- Daphne
- Cotoneaster
- Taxus
- Several broad leaf evergreens

The amount of sludge applied varies with the crop. For field crops the application varies from 6 to 10 tons per acre, but additions up to 40 tons per acre have produced good results. A number of nursery men have reported good results with young trees and shrubs with sludge used in a manner and in quantities such as would be used if the material were barn-yard manure.

Over-All Value

The *fertility* values together with the *fertilizer* value of sewage sludges may be summarized in general as follows:

In addition to relatively small amounts of the principal fertilizer ingredients, sewage sludge contains "minor" chemical elements and growth-promoting substances essential and necessary for proper plant growth. It prevents depletion of humus and is capable of increasing the fertility of the soil. It improves the soil structure in general and increases the water holding capacity of sandy soil in particular. The value of sludge is not the same for all soils, neither is it the same for all crops. Except for growth observations there is no adequate measuring-stick for revealing the over-all value of sewage sludges as soil improvers and growth promoters—in short, their fertility values as contrasted to their limited worth as fertilizers, based on the chemist's analysis alone.

ENGINEERING DATA

CONVERSION FACTORS FOR ENGINEERS*

The word gallon, used in any conversion factor, designates the U. S. gallon. Likewise, the word ton designates a short ton, 2,000 pounds.

The figures 10^{-1}, 10^{-2}, 10^{-3}, etc., denote 0.1, 0.01, 0.001, etc., respectively.

The figures 10^{1}, 10^{2}, 10^{3}, etc., denote 10, 100, 1000, etc.. respectively.

"Parts Per Million," (designated as p.p.m.), is always by weight. As used in the sanitary field, p.p.m. represents the number of pounds of dry solids contained in one million pounds of water. In this field, one part per million may be expressed as 8.345 pounds of dry solids to one million U. S. gallons of water.

Multiply	By	To Obtain
Acres	43,560	Square feet
"	4047	Square meters
Acre-feet	43,560	Cubic feet
" "	325,851	Gallons
" "	1233.49	Cubic meters
Atmospheres	29.92	Inches of mercury
"	33.90	Feet of water
"	76.0	Cms. of mercury
"	14.70	Lbs./sq. inch
Barrels cement	376	Pounds—cement
Bags or sacks-cement	94	Pounds— "
British Thermal Units	777.5	Foot-lbs.
" " "	3.927×10^{-4}	Horse-power-hrs.
" " "	2.928×10^{-4}	Kilowatt-hrs.
" " "	0.2520	Kilogram-calories
" " "	107.5	Kilogram-meters
B.T.U./min.	12.96	Foot-lbs./sec.
" "	0.02356	Horse-power
" "	0.01757	Kilowatts
Centimeters	0.3937	Inches
Centimeters of mercury	0.01316	Atmospheres
" " "	0.4461	Feet of water
" " "	27.85	Lbs./sq. ft.
" " "	0.1934	Lbs./sq. inch
Centimeters/second	1.969	Feet/min.
" "	0.03281	Feet/sec.
" "	0.6	Meters/min.
Cubic centimeters	3.531×10^{-5}	Cubic feet
" "	6.102×10^{-2}	Cubic inches
" "	2.642×10^{-4}	Gallons
" "	10^{-6}	Cubic meters
" "	10^{-3}	Liters
Cubic feet	7.48052	Gallons
" "	1728	Cubic inches
" "	0.03704	Cubic yards
" "	28.32	Liters
" "	2.832×10^{4}	Cubic cms.
" "	0.02832	Cubic meters
Cubic feet/second	0.646317	Million gals./day
" " "	448.831	Gallons/min.
Cubic inches	16.39	Cubic centimeters
" "	5.787×10^{-4}	Cubic feet
" "	1.639×10^{-5}	Cubic meters
" "	4.329×10^{-3}	Gallons
" "	1.639×10^{-2}	Liters
Cubic meters	35.31	Cubic feet
" "	1.308	Cubic yards
" "	264.2	Gallons
" "	10^{3}	Liters
Cubic yards	27	Cubic feet
" "	46.656	Cubic inches
" "	0.7646	Cubic meters
" "	202.0	Gallons
" "	764.6	Liters
Drams	27.34375	Grains
"	0.0625	Ounces
"	1.771845	Grams
Fathoms	6	Feet
Feet	30.48	Centimeters
"	0.3048	Meters
Feet of water	0.8826	Inches of mercury
" " "	0.4335	Lbs./sq. inch
" " "	62.43	Lbs./sq. ft.
" " "	0.02950	Atmospheres
" " "	304.8	Kgs./sq. meter
Feet/sec.	30.48	Centimeters/sec.
" "	18.29	Meters/min.
Foot-pounds	1.286×10^{-3}	British thermal units
" "	5.050×10^{-7}	Horse-power-hrs.
" "	0.1383	Kilogram-meters
" "	3.766×10^{-7}	Kilowatt-hrs.
Foot-pounds/min.	3.030×10^{-5}	Horse-power
" " "	2.260×10^{-5}	Kilowatts
Gallons	0.1337	Cubic feet
"	231	Cubic inches
"	3785	Cubic centimeters
"	3.785×10^{-3}	Cubic meters
"	3.785	Liters
Gallons, Imperial	1.200095	U. S. gallons
" U. S.	0.83267	Imperial gallons
Gallons water	8.3453	Pounds of water
Gallons/min.	2.228×10^{-3}	Cubic feet/sec.
" "	0.06308	Liters/sec.
" "	8.0208	Cu. ft./hr.
Grains (troy)	1	Grains (avoir.)
"	0.06480	Grams
Grains/U.S. gal.	17.118	Parts/million
" /U.S. gal.	142.86	Lbs./million gal.
" /Imp. gal.	14.254	Parts/million
Grams	15.43	Grains
"	0.03527	Ounces
"	980.7	Dynes
Grams/liter	58.417	Grains/gal.
" "	8.345	Pounds/1000 gals.
" "	1000	Parts/million
Hectares	2.471	Acres
Horse-power	42.44	B.T. Units/min.
" "	550	Foot-lbs./sec.
" "	0.7457	Kilowatts
Horse-power (boiler)	33,479	B.T.U./hr.
" " "	9.803	Kilowatts
Inches	2.540	Centimeters
Inches of mercury	1.133	Feet of water
" " "	0.4912	Lbs./sq. inch
" " "	0.03342	Atmospheres
" " "	345.3	Kgs./sq. meter
Inches of water	0.07355	Inches of mercury
" " "	0.03613	Lbs./sq. inch
Kilograms	2.205	Lbs.
Kilograms-calories/min.	51.43	Foot-pounds/sec.
" " "	0.09351	Horse-power
" " "	0.06972	Kilowatts
Kgs./sq. meter	3.281×10^{-3}	Feet of water
" " "	1.422×10^{-3}	Lbs./sq. inch
Kilometers	3281	Feet
"	0.6214	Miles
Kilometers/hr.	0.9113	Feet/sec.
" "	27.78	Centimeters/sec.
Kilowatts	56.92	B.T. Units/min.
"	737.6	Foot-lbs./sec.
"	1.341	Horse-power
"	14.34	Kg.-calories/min.
Liters	0.2642	Gallons
"	61.02	Cubic inches
"	0.03531	Cubic feet
Meters	3.281	Feet
"	39.37	Inches
"	1.094	Yards
Miles	5280	Feet
"	1.609	Kilometers
Miles/min.	88	Feet/sec.
" "	1.609	Kilometers/min
Milligrams/liter	1	Parts/million
Million gals./day	1.54723	Cubic ft./sec.
Miner's inches	1.5	Cubic ft./min.
Ounces	28.349527	Grams
"	437.5	Grains
"	0.9115	Ounces (troy)
Ounces (fluid)	1.805	Cubic inches
" "	29.57	Cubic cm.
Parts/million	8.345	Lbs./million gal.
" "	0.0584	Grains/U. S. gal.
" "	0.07016	Grains/Imp. gal.
Pounds	16	Ounces
"	7000	Grains
"	453.5924	Grams
"	1.21528	Pounds (troy)

*Selections from a booklet of—"Conversion Factors for Engineers"—distributed by The Dorr Co., New York City.

Multiply	By	To Obtain
Pounds of water	0.01602	Cubic feet
" " "	27.68	Cubic inches
" " "	0.1198	Gallons
Pounds/cubic foot	0.01602	Grams/cubic cm.
" " "	16.02	Kgs./cubic meter
" " "	5.787×10^{-4}	Lbs./cubic inch
Pounds/foot	1.488	Kgs./meter
Pounds/inch	178.6	Grams/cm.
Pounds/sq. foot	0.01602	Feet of water
" " "	4.883	Kgs./sq. meter
Pounds/sq. inch	2.307	Feet of water
" " "	2.036	Inches of mercury
" " "	0.06804	Atmospheres
" " "	703.1	Kgs./sq. meter
Quires	25	Sheets
Reams	500	Sheets
Square centimeters	0.1550	Square inches
" "	1.076×10^{-3}	Square feet
Square feet	144	Square inches
" "	0.09290	Square meters
" "	2.296×10^{-5}	Acres
Square inches	6.452	Square centimeters

Multiply	By	To Obtain
Square kilometers	247.1	Acres
" "	10.76×10^{6}	Square feet
" "	1.196×10^{6}	Square yards
Square meters	10.76	Square feet
" "	1.196	Square yards
Square miles	640	Acres
" "	27.88×10^{6}	Square feet
" "	2.590	Square Kilometers
Square yards	9	Square feet
" "	0.8361	Square meters
" "	2.066×10^{-4}	Acres
Tons (long)	1016	Kilograms
" "	2240	Pounds
" "	1.12000	Tons (short)
Tons (metric)	10^{3}	Kilograms
" "	2205	Pounds
Tons (short)	2000	Pounds
" "	907.18486	Kilograms
Tons of water/24 hrs.	0.16643	Gallons/min.
Watts	0.05692	B.T.Units/min.
"	0.7376	Foot-pounds/sec.
"	1.341×10^{-3}	Horse-power
"	0.01434	Kg.-calories/min.
Yards	0.9144	Meters

Relative Carrying Capacities of Pipe Lines of Equal Smoothness

Prepared by Emil L. Neubling for the Reading Meter Repair Co.

Diameter of Pipes	⅛	¼	⅜	½	¾	1	1¼	1½	2	2½
26										348.81
24										285.55
22										229.20
20									316.23	181.02
18									243.00	139.10
16								371.60	181.02	103.62
15								316.23	154.05	88.18
14							419.80	266.13	129.64	74.21
12							285.55	181.02	88.18	50.48
10						316.23	181.02	114.76	55.90	32.00
9						243.00	139.10	88.18	42.96	24.65
8					371.60	181.02	103.62	65.69	32.00	18.32
7					266.13	129.64	74.21	47.05	22.92	13.12
6					181.02	88.18	50.48	32.00	15.59	8.92
5				316.23	114.76	55.90	32.00	20.29	9.88	5.66
4½				243.00	88.18	42.96	24.65	15.59	7.59	4.35
4			371.60	181.02	65.69	32.00	18.32	11.61	5.66	3.24
3½			266.13	129.64	47.05	22.92	13.12	8.32	4.05	2.32
3			181.02	88.18	32.00	15.59	8.92	5.66	2.76	1.58
2½		316.23	114.76	55.90	20.29	9.88	5.66	3.59	1.75	1.00
2		181.02	65.69	32.00	11.61	5.66	3.24	2.05	1.00	
1½		88.18	32.00	15.59	5.66	2.76	1.58	1.00		
1¼	316.23	55.90	20.29	9.88	3.59	1.75	1.00			
1	181.02	32.00	11.61	5.66	2.05	1.00				
¾	88.18	15.59	5.66	2.05	1.00					
½	32.00	5.66	2.05	1.00						
⅜	15.59	2.76	1.00							
¼	5.66	1.00								
⅛	1.00									

Diameter of Pipes	3	3½	4	4½	5	6	7	8	9	10
48			498.83	371.60	285.55	181.02	123.13	88.18	65.69	50.48
46			448.48	334.09	256.73	162.75	110.70	79.10	59.06	45.38
44			401.31	298.96	229.20	145.63	99.29	70.94	52.85	40.61
42			357.25	243.00	204.50	129.64	88.18	63.15	47.05	36.15
40			316.23	235.57	181.02	114.76	78.06	55.90	41.64	32.00
38		388.41	278.17	207.22	159.23	100.94	68.66	49.17	36.63	28.15
36		339.30	243.00	181.02	139.10	88.18	59.98	42.96	32.00	24.65
34		294.12	210.64	156.92	120.58	76.44	51.99	37.24	27.74	21.32
32		252.76	181.02	134.85	103.62	65.69	44.68	32.00	23.84	18.32
30	316.23	215.10	154.05	114.76	88.18	55.90	38.02	27.23	20.29	15.59
28	266.13	181.02	129.64	96.57	74.21	47.05	32.00	22.92	17.07	13.12
26	221.12	150.41	107.72	80.24	61.66	39.09	26.59	19.04	14.18	10.90
24	181.02	123.13	88.18	65.69	50.48	32.00	21.77	15.59	11.61	8.92
22	145.63	99.29	70.94	52.85	40.61	25.74	17.51	12.54	9.34	7.18
20	114.76	78.06	55.90	41.64	32.00	20.29	13.80	9.88	7.36	5.66
18	88.18	59.98	42.96	32.00	24.65	15.59	10.60	7.59	5.66	4.35
16	65.69	44.68	32.00	23.84	18.32	11.61	7.90	5.66	4.21	3.24
15	55.90	38.02	27.23	20.29	15.59	9.88	6.72	4.81	3.59	2.76
14	47.05	32.00	22.92	17.07	13.12	8.32	5.66	4.05	3.02	2.32
12	32.00	21.77	15.59	11.61	8.92	5.66	3.85	2.76	2.05	1.58
10	20.29	13.80	9.88	7.36	5.66	3.59	2.44	1.75	1.30	1.00
9	15.59	10.60	7.59	5.66	4.35	2.76	1.83	1.34	1.00	
8	11.61	7.90	5.66	4.21	3.24	2.05	1.40	1.00		
7	8.32	5.66	4.05	3.02	2.32	1.47	1.00			
6	5.66	3.85	2.76	2.05	1.58	1.00				
5	3.59	2.44	1.77	1.30	1.00					
4½	2.76	1.83	1.34	1.00						
4	2.05	1.40	1.00							
3½	1.47	1.00								
3	1.00									

Diameter of Pipes	12	14	15	16	18	20	22	24	26	28
48	32.00	21.77	18.32	15.59	11.61	8.92	7.03	5.66	4.63	3.85
46	28.77	19.57	16.47	14.02	10.44	8.02	6.32	5.09	4.16	3.46
44	25.74	17.51	14.71	12.54	9.34	7.13	5.66	4.55	3.73	3.10
42	22.92	15.59	13.12	11.16	8.32	6.39	5.04	4.05	3.32	2.76
40	20.29	13.80	11.61	9.88	7.36	5.66	4.46	3.59	2.94	2.44
38	17.84	12.14	10.21	8.69	6.48	4.98	3.92	3.15	2.58	2.17
36	15.59	10.60	8.92	7.59	5.66	4.35	3.43	2.76	2.26	1.83
34	13.51	9.19	7.74	6.58	4.90	3.77	2.97	2.39	1.96	1.62
32	11.61	7.90	6.65	5.66	4.21	3.24	2.55	2.05	1.68	1.40
30	9.88	6.72	5.66	4.81	3.59	2.76	2.17	1.75	1.43	1.19
28	8.32	5.66	4.76	4.05	3.02	2.32	1.83	1.47	1.20	1.00
26	6.91	4.70	3.96	3.37	2.51	1.93	1.52	1.22	1.00	
24	5.66	3.85	3.24	2.76	2.05	1.58	1.24	1.00		
22	4.55	3.10	2.61	2.22	1.65	1.27	1.00			
20	3.59	2.44	2.05	1.75	1.30	1.00				
18	2.76	1.83	1.58	1.34	1.00					
16	2.05	1.40	1.18	1.00						
15	1.75	1.19	1.00							
14	1.47	1.00								
12	1.00									

Diameter of Pipes	30	32	34	36	38	40	42	44	46	48
48	3.24	2.76	2.37	2.05	1.80	1.58	1.40	1.24	1.11	1.00
46	2.91	2.48	2.13	1.85	1.61	1.42	1.26	1.12	1.00	
44	2.61	2.22	1.91	1.65	1.44	1.27	1.12	1.00		
42	2.32	1.97	1.70	1.47	1.28	1.13	1.00			
40	2.05	1.75	1.50	1.30	1.14	1.00				
38	1.81	1.54	1.32	1.14	1.00					
36	1.58	1.34	1.15	1.00						
34	1.37	1.16	1.00							
32	1.18	1.00								
30	1.00									

The foregoing tables will be found useful in proportioning distribution lines.

Example: To find how many one-half inch pipes can be supplied by a 4-in. line, follow down the ½-in. vertical column to the number opposite 4-in. diameter of the first column, where the number 181.02 is found, which is the number of one-half inch lines that can be supplied by a 4-in. line.

Example: To find how many 12-in. lines can be supplied by a 48-in. line, follow horizontally along the 48-in. diameter of the first column, until you reach the 12-in. vertical column, where the number 32 is found, which is the result desired.

CHART FOR CONVERTING GRAINS PER GALLON TO POUNDS PER MILLION AND THE REVERSE

Courtesy W. Donaldson and Fuller & McClintock, Engineers

POUNDS OF CHEMICAL REQUIRED PER HOUR FOR VARIOUS PUMPAGES & DOSES

PUMPAGE		DOSE - POUNDS PER MILLION GALLONS															
MILLION GALLONS 24 HRS.	THOUSAND GALLONS PER HOUR	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
		DOSE - GRAINS PER GALLON															
		.07	.14	.21	.28	.35	.42	.49	.56	.63	.70	.77	.84	.91	.98	1.05	1.12
1.0	41.7	.417	.833	1.25	1.67	2.08	2.50	2.92	3.33	3.75	4.17	4.58	5.00	5.42	5.83	6.25	6.67
1.5	62.5*	.625	1.25	1.88	2.50	3.13	3.75	4.38	5.00	5.63	6.25	6.88	7.50	8.13	8.75	9.38	10.0
2.0	83.3	.833	1.67	2.50	3.33	4.17	5.00	5.83	6.67	7.50	8.33	9.17	10.0	10.8	11.7	12.5	13.3
2.5	104	1.04	2.08	3.13	4.17	5.21	6.25	7.29	8.33	9.38	10.4	11.5	12.5	13.5	14.6	15.6	16.7
3.0	125*	1.25	2.50	3.75	5.00	6.25	7.50	8.75	10.0	11.3	12.5	13.8	15.0	16.3	17.5	18.8	20.0
3.5	146	1.46	2.92	4.38	5.83	7.29	8.75	10.2	11.7	13.1	14.6	16.0	17.5	19.0	20.4	21.9	23.3
4.0	167	1.67	3.33	5.00	6.67	8.33	10.0	11.7	13.3	15.0	16.7	18.3	20.0	21.7	23.3	25.0	26.7
4.5	187	1.88	3.75	5.63	7.50	9.38	11.3	13.1	15.0	16.9	18.8	20.6	22.5	24.4	26.3	28.1	30.0
5.0	208	2.08	4.17	6.25	8.33	10.4	12.5	14.6	16.7	18.8	20.8	22.9	25.0	27.1	29.2	31.3	33.3
5.5	229	2.29	4.58	6.88	9.17	11.5	13.8	16.0	18.3	20.6	22.9	25.2	27.5	29.8	32.1	34.4	36.7
6.0	250*	2.50	5.00	7.50	10.0	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0	32.5	35.0	37.5	40.0
6.5	271	2.71	5.42	8.13	10.8	13.5	16.3	19.0	21.7	24.4	27.1	29.8	32.5	35.2	37.9	40.6	43.3
7.0	292	2.92	5.83	8.75	11.7	14.6	17.5	20.4	23.3	26.3	29.2	32.1	35.0	37.9	40.8	43.8	46.7
7.5	312	3.13	6.25	9.38	12.5	15.6	18.8	21.9	25.0	28.1	31.3	34.4	37.5	40.6	43.8	46.9	50.0
8.0	333	3.33	6.68	10.0	13.3	16.7	20.0	23.3	26.7	30.0	33.3	36.7	40.0	43.3	46.7	50.0	53.3
8.5	354	3.54	7.08	10.6	14.2	17.7	21.3	24.8	28.3	31.9	35.4	39.0	42.5	46.0	49.6	53.1	56.7
9.0	375*	3.75	7.50	11.3	15.0	18.8	22.5	26.3	30.0	33.8	37.5	41.3	45.0	48.8	52.5	56.3	60.0
9.5	396	3.96	7.92	11.9	15.8	19.8	23.8	27.7	31.7	35.6	39.6	43.5	47.5	51.5	55.4	59.4	63.3
10.0	417	4.17	8.33	12.5	16.7	20.8	25.0	29.2	33.3	37.5	41.7	45.8	50.0	54.2	58.3	62.5	66.7
10.5	437	4.38	8.75	13.1	17.5	21.9	26.3	30.6	35.0	39.4	43.8	48.1	52.5	56.9	61.3	65.6	70.0
11.0	458	4.58	9.17	13.8	18.3	22.9	27.5	32.1	36.7	41.3	45.8	50.4	55.0	59.6	64.2	68.8	73.3
11.5	479	4.79	9.58	14.4	19.2	24.0	28.8	33.5	38.3	43.1	47.9	52.7	57.5	62.3	67.1	71.9	76.7
12.0	500*	5.00	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
12.5	521	5.21	10.4	15.6	20.8	26.0	31.3	36.5	41.7	46.9	52.1	57.3	62.5	67.7	72.9	78.1	83.3
13.0	542	5.42	10.8	16.3	21.7	27.1	32.5	37.9	43.3	48.8	54.2	59.6	65.0	70.4	75.8	81.3	86.7
13.5	562	5.63	11.3	16.9	22.5	28.1	33.8	39.4	45.0	50.6	56.3	61.9	67.5	73.1	78.8	84.4	90.0
14.0	583	5.83	11.7	17.5	23.3	29.2	35.0	40.8	46.7	52.5	58.3	64.2	70.0	75.8	81.7	87.5	93.3
14.5	604	6.04	12.1	18.1	24.2	30.2	36.3	42.3	48.3	54.4	60.4	66.5	72.5	78.5	84.6	90.6	96.7
15.0	625*	6.25	12.5	18.8	25.0	31.3	37.5	43.8	50.0	56.3	62.5	68.8	75.0	81.3	87.5	93.8	100.0

* Exact Values

1 grain per gallon = 143 pounds per million gallons = 5.95 lbs. per hour for each million gallons
0.70 " " " = 100 " " " " = 4.17 " " " " " "

Courtesy Fuller & McClintock Engineers

Example: What weight of Chemical must be fed each hour to give a 70 lb dose for a pumpage of 8.0 M.G.D. Opposite 8.0 M.G.D and under 70 find 23.3, which is the correct weight.

Note: It is now becoming modern practice to record and report all chemical dosages in pounds per million (P.M.G.) and thereby have simplification in reporting and recording, rather than using the older scheme involving grains per gallon, parts per million, etc.

NUMBER OF TAPS THAT CAN BE TAKEN FROM PIPE OF VARIOUS SIZES

Diameter of Pipe in Inches	SIZE OF TAPS IN INCHES																						
	¾	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	12	14	15	16	18	20	22	24
2	11	5	3	2	1																			
2½	20	9	5	3	1	1																		
3	32	15	8	5	2	1	1																	
3½	47	22	13	8	4	2	1	1																
4	65	32	18	11	5	3	2	1	1															
4½	88	42	24	15	7	4	2	1	1	1														
5	114	55	32	20	9	5	3	2	1	1	1													
6	181	88	50	32	15	8	5	3	2	2	1	1												
7	266	129	74	47	22	13	8	5	4	3	2	1	1											
8	371	181	103	65	32	18	11	7	5	4	3	2	1	1										
9		243	139	88	42	24	15	10	7	5	4	2	1	1	1									
10		316	181	114	55	32	20	13	9	7	5	3	2	1	1	1								
12			285	181	88	50	32	21	15	11	8	5	3	2	2	1	1							
14			419	266	129	74	47	32	22	17	13	8	5	4	3	2	1	1						
15				316	154	88	55	38	27	20	15	9	6	4	3	2	1	1	1					
16				371	181	103	65	44	32	23	18	11	7	5	4	3	2	1	1	1				
18					243	139	88	59	42	32	24	15	10	7	5	4	2	1	1	1	1			
20					316	181	114	78	55	41	32	20	13	9	7	5	3	2	2	1	1	1		
22						229	145	99	70	52	40	25	17	12	9	7	4	3	2	2	1	1	1	
24						285	181	123	88	65	50	32	21	15	11	8	5	3	3	2	2	1	1	1

Cylindrical Tank Capacities Per Foot of Depth

(The Cubic Foot Figure Is Also the Area in Each Instance)

Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.
1	0.785	5.87	9	63.62	475.9	20	314.2	2350	32	804.3	6016	58	2642	19760
1-3	1.227	9.18	9-6	70.88	530.2	20-6	330.1	2469	33	855.3	6398	60	2827	21150
1-6	1.767	13.22	10	78.54	587.5	21	346.4	2591	34	907.9	6792	62	3019	22580
1-9	2.405	17.99	10-6	86.59	647.7	21-6	363.1	2716	35	962.1	7197	64	3217	24060
2	3.142	23.50	11	95.03	710.9	22	380.1	2844	36	1018	7616	66	3421	25590
2-3	3.976	29.74	11-6	103.9	777.0	22-6	397.6	2974	37	1075	8043	68	3632	27170
2-6	4.909	36.72	12	113.1	846.0	23	415.5	3108	38	1134	8483	70	3848	28790
2-9	5.940	44.43	12-6	122.7	918.0	23-6	433.7	3245	39	1195	8940	72	4072	30450
3	7.069	52.88	13	132.7	992.9	24	452.4	3384	40	1257	9404	74	4301	32170
3-3	8.296	62.06	13-6	143.1	1071	24-6	471.4	3527	41	1320	9876	76	4536	33930
3-6	9.621	71.97	14	153.9	1152	25	490.9	3672	42	1385	10360	78	4778	35740
3-9	11.04	82.62	14-6	165.1	1235	25-6	510.7	3820	43	1452	10860	80	5027	37600
4	12.57	94.00	15	176.7	1322	26	530.9	3972	44	1521	11370	82	5281	39500
4-6	15.90	119.0	15-6	188.7	1412	26-6	551.5	4126	45	1590	11900	84	5542	41450
5	19.63	146.9	16	201.1	1504	27	572.6	4283	46	1662	12430	86	5809	43450
5-6	23.76	177.7	16-6	213.8	1600	27-6	594.0	4443	47	1735	12980	88	6082	45490
6	28.27	211.5	17	227.0	1698	28	615.8	4606	48	1810	13540	90	6362	47590
6-6	33.18	248.2	17-6	240.5	1799	28-6	637.9	4772	49	1886	14110	92	6648	49720
7	38.48	287.9	18	254.5	1904	29	660.5	4941	50	1964	14690	94	6940	51920
7-6	44.18	330.5	18-6	268.8	2011	29-6	683.5	5113	52	2124	15890	96	7238	54140
8	50.27	376.0	19	283.5	2121	30	706.9	5288	54	2290	17130	98	7543	56420
8-6	56.75	424.5	19-6	298.6	2234	31	754.8	5646	56	2463	18420	100	7854	58750

WATER PRESSURE

Feet of Head ⇄ Pressure

Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.
1	0.43	54	23.39	107	46.34	160	69.31	213	92.20	285	123.45
2	0.86	55	23.82	108	46.78	161	69.74	214	92.69	290	125.62
3	1.30	56	24.26	109	47.21	162	70.17	215	93.13	295	127.78
4	1.73	57	24.69	110	47.64	163	70.61	216	93.56	300	129.95
5	2.16	58	25.12	111	48.08	164	71.04	217	92.99	305	132.12
6	2 59	59	25.55	112	48.51	165	71.47	218	94.43	310	134.28
7	3.03	60	25.99	113	48.94	166	71.91	219	94.86	315	136.46
8	3.46	61	26.42	114	49.38	167	72.34	220	95.30	320	138.62
9	3.89	62	26.85	115	49.81	168	72.77	221	95.73	325	140.79
10	4.33	63	27.29	116	50.24	169	73.20	222	96.16	330	142.95
11	4.76	64	27.72	117	50.68	170	73.64	223	96.60	335	145.12
12	5.20	65	28.15	118	51.11	171	74.07	224	97.03	340	147.28
13	5.63	66	28.58	119	51.54	172	74.50	225	97.46	345	149.45
14	6.06	67	29.02	120	51.98	173	74.94	226	97.90	350	151.61
15	6.49	68	29.45	121	52.41	174	75.37	227	98.33	355	153.78
16	6.93	69	29.88	122	52.84	175	75.80	228	98.76	360	155.94
17	7.36	70	30.32	123	53.28	176	76.23	229	99.20	365	158.10
18	7.79	71	30.75	124	53.71	177	76.67	230	99.63	370	160.27
19	8 22	72	31.18	125	54.15	178	77.10	231	100.0	375	162.45
20	8.66	73	31.62	126	54.58	179	77.53	232	100.49	380	164.61
21	9.09	74	32.05	127	55.01	180	77.97	233	100.93	385	166.78
22	9.53	75	32.48	128	55.44	181	78.40	234	101.36	390	168.94
23	9.96	76	32.92	129	55.88	182	78.84	235	101.70	395	171.11
24	10.39	77	33.35	130	56.31	183	79.27	236	102.23	400	173.27
25	10.82	78	33.78	131	56.74	184	79.70	237	102.66	425	184.10
26	11.26	79	34.21	132	57.18	185	80.14	238	103.09	450	195.0
27	11.69	80	34.65	133	57.61	186	80.57	239	103.53	475	205.77
28	12.12	81	35.08	134	58.04	187	81.0	240	103.96	500	216.58
29	12.55	82	35.52	135	58.48	188	81.43	241	104.39	525	227.42
30	12.99	83	35.95	136	58.91	189	81.87	242	104.83	550	238.25
31	13 42	84	36.39	137	59.34	190	82.30	243	105.26	575	249.09
32	13.86	85	36.82	138	59.77	191	82.73	244	105.69	600	259.90
33	14.29	86	37.25	139	60.21	192	83.17	245	106.13	625	270.73
34	14.72	87	37.68	140	60.64	193	83.60	246	106.56	650	281.56
35	15.16	88	38.12	141	61.07	194	84.03	247	106.99	675	292.40
36	15.59	89	38.55	142	61.51	195	84 47	248	107.43	700	303.22
37	16.02	90	39.08	143	61.94	196	84.90	249	107.86	725	314.05
38	16.45	91	39.42	144	62.37	197	85 33	250	108.29	750	324.88
39	16.89	92	39.85	145	62.81	198	85.76	251	108.73	775	335.72
40	17.32	93	40.28	146	63.24	199	86.20	252	109.16	800	346.54
41	17.75	94	40.72	147	63.67	200	86.63	253	109.59	825	357.37
42	18.19	95	41.15	148	64.10	201	87 07	254	110.03	850	368.20
43	18.62	96	41.58	149	64.54	202	87.50	255	110.46	875	379.03
44	19 05	97	42.01	150	64.97	208	87.93	256	110.89	900	389.86
45	19 49	98	42.45	151	65.40	204	88.36	257	111.32	925	400.70
46	19.92	99	42.88	152	65.84	205	88.80	258	111.76	950	411.54
47	20.35	100	43.31	153	66.27	206	89.21	259	112.19	975	422.35
48	20.79	101	43.75	154	66.70	207	89.66	260	112.62	1000	433.18
49	21.22	102	44.18	155	67.14	208	90.10	261	113.06	1500	649.7
50	21.65	103	44.61	156	67.57	209	90.53	262	113.49	2000	866.3
51	22.09	104	45.05	157	68.0	210	90.96	270	116.96	3000	1299.5
52	22.52	105	45.48	158	68.43	211	91.39	275	119.12		
53	22.95	106	45.91	159	68 87	212	91.83	280	121.29		

Based on a density of 62.355 pounds per cu. ft. for water at 62°F.

Theoretical Horsepower

$$\text{Water Horsepower} = \frac{\text{G. P. M.} \times \text{Head in Feet}}{3960}$$

HEAD IN FEET

Gallons per minute	10	15	20	25	30	35	40	45	50	60	75	90	100
10	03	04	05	06	08	09	10	.11	.13	.15	.19	.23	.25
15	.04	.06	.08	.09	.11	.13	.15	.17	.19	.23	.28	.34	.38
20	.05	.08	.10	.13	.15	.18	.20	.22	.25	.30	.38	.45	.50
25	.06	.10	.13	.16	.19	.22	.25	.28	.32	.38	'47	.57	.68
30	.08	.11	.15	.19	.23	.26	.30	.34	.38	.45	.57	.68	.75
35	.09	.13	.18	.22	26	.31	.35	.40	.44	.53	.66	.80	.88
40	.10	.15	.20	.25	.30	.35	.40	.45	.50	.61	.76	.91	1.01
45	.11	.17	.23	.28	34	.40	.45	.51	.57	.68	.85	1.02	1.14
50	.13	.19	.25	.32	.38	.44	.50	.57	.63	.76	.95	1.14	1.26
60	.15	.23	.30	.38	.46	.53	.61	.68	.76	.91	1.14	1.36	1.52
75	.19	.28	.38	.47	.57	.66	.76	85	.95	1.14	1.42	1.70	1.89
90	.23	.34	.45	.57	.68	.80	.91	1.02	1.14	1.36	1.70	2.04	2.27
100	.25	.38	.50	63	.76	.88	1 01	1.14	1.26	1 51	1.89	2.27	2.52
125	.32	.47	.63	.79	.97	1.10	1.26	1.42	1.58	1.89	1.37	2.84	3.16
150	.38	.57	.76	.95	1 14	1.32	1.52	1.70	1.89	2.27	2.84	3.41	3.79
175	.44	.66	.88	1.10	1.32	1.54	1.78	1.99	2.21	2.65	3.31	3.98	4.42
200	.50	.76	1 01	1.26	1.52	1.77	2.02	2.27	2.52	3 03	3.79	4.54	5.05
250	.63	.95	1.26	1.58	1.90	2.20	2.52	2.84	3.16	3.79	4.73	5.68	6.31
300	.76	1.14	1.51	1.90	2.27	2.65	3.03	3.41	3.79	4.54	5.68	6.82	7.58
350	.88	1.33	1.77	2.21	2.65	3.09	3.54	3.98	4.42	5 30	6.62	7.95	8.84
400	1.01	1 52	2.02	2.52	3.03	3.53	4.04	4.55	5.05	6.06	7.57	9 09	10.10
500	1.26	1.90	2.52	3.16	3 78	4.42	5.05	5.69	6 31	7 58	9.47	11.36	12.63
550	1.39	2.08	2.78	3.47	4.17	4.86	5 56	6.26	6.94	8.33	10.42	12.50	13.89
600	1.52	2.28	3.03	3.79	4.55	5.30	6 06	6.82	7.58	9.09	11.36	13.64	15.15
650	1.64	2.47	3.28	4.10	4.93	5.75	6.56	7 39	8.21	9.85	12.31	14.77	16.41
700	1.77	2.66	3.54	4.42	5.30	6.19	7.07	7.96	8.84	10.60	13.26	15.91	17.68
750	1.89	2.85	3.79	4.74	5.68	6 63	7 58	8.53	9.47	11.36	14.20	17.04	18.94
800	2.02	3.04	4.04	5.05	6.06	7.07	8.08	9.10	10 10	12.12	15.15	18.18	20.20
850	2.15	3.23	4 29	5.37	6.44	7.51	8.58	9.67	10.73	12.87	16.10	19.32	21.46
900	2.27	3.42	4.54	5.68	6.82	7.95	9.09	10.24	11.36	13 63	17.04	20.45	22.73
950	2.40	3.60	4 80	6.00	7.20	8.40	9.60	10.80	11.99	14.39	17.99	21.59	23.99
1000	2.52	3.79	5.05	6.31	7.58	8.84	10.10	11.36	12.63	15 15	18.94	22.73	25.25
2000	5.05	7.57	10 10	12.63	15.15	17.67	20.20	22.72	25.25	30.30	37.87	45.45	50.50
3000	7.57	11.37	15.15	18.94	22.72	26.51	30.30	34.09	37.88	45.45	56.81	68.18	75.75
4000	10.10	15.16	20.20	25 25	30.30	35.35	40 40	45.45	50.50	60.60	75.75	90.90	101.01

NOTE:—to get the BRAKE HORSEPOWER required by the pump use the following formula:—

$$\text{Brake Horsepower} = \frac{\text{G. P. M. x Head in Feet}}{3960 \text{ x Effy. of the pump}}$$

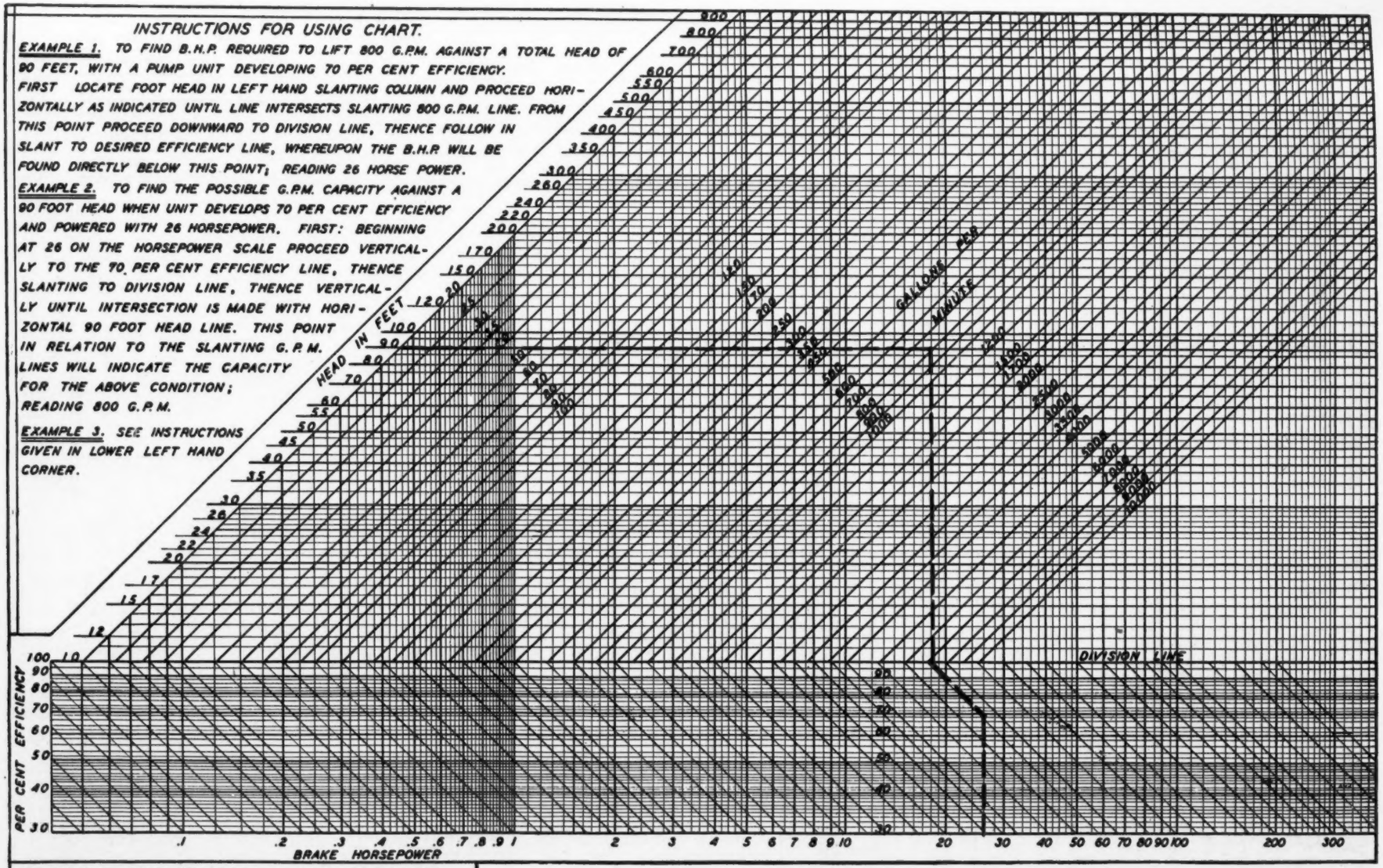

INSTRUCTIONS FOR USING CHART.
EXAMPLE 1. TO FIND B.H.P. REQUIRED TO LIFT 800 G.P.M. AGAINST A TOTAL HEAD OF 90 FEET, WITH A PUMP UNIT DEVELOPING 70 PER CENT EFFICIENCY. FIRST LOCATE FOOT HEAD IN LEFT HAND SLANTING COLUMN AND PROCEED HORIZONTALLY AS INDICATED UNTIL LINE INTERSECTS SLANTING 800 G.P.M. LINE. FROM THIS POINT PROCEED DOWNWARD TO DIVISION LINE, THENCE FOLLOW IN SLANT TO DESIRED EFFICIENCY LINE, WHEREUPON THE B.H.P. WILL BE FOUND DIRECTLY BELOW THIS POINT; READING 26 HORSE POWER.
EXAMPLE 2. TO FIND THE POSSIBLE G.P.M. CAPACITY AGAINST A 90 FOOT HEAD WHEN UNIT DEVELOPS 70 PER CENT EFFICIENCY AND POWERED WITH 26 HORSEPOWER. FIRST: BEGINNING AT 26 ON THE HORSEPOWER SCALE PROCEED VERTICALLY TO THE 70 PER CENT EFFICIENCY LINE, THENCE SLANTING TO DIVISION LINE, THENCE VERTICALLY UNTIL INTERSECTION IS MADE WITH HORIZONTAL 90 FOOT HEAD LINE. THIS POINT IN RELATION TO THE SLANTING G.P.M. LINES WILL INDICATE THE CAPACITY FOR THE ABOVE CONDITION; READING 800 G.P.M.
EXAMPLE 3. SEE INSTRUCTIONS GIVEN IN LOWER LEFT HAND CORNER.
HEAD IN FEET
GALLONS PER MINUTE
DIVISION LINE
PER CENT EFFICIENCY
BRAKE HORSEPOWER
EXAMPLE 3. TO FIND THE EFFICIENCY A PUMP MUST DEVELOP IN ORDER TO DELIVER 800 G.P.M. AGAINST A 90 FOOT HEAD WITH 26 HORSEPOWER. PROCEED AS IN EXAMPLE 1 TO DIVISION LINE, THEN SLANTWISE UNTIL INTERSECTION IS MADE WITH THE VERTICAL 26 HORSEPOWER LINE. THIS POINT WILL LOCATE THE HORIZONTAL EFFICIENCY LINE; READING 70 PER CENT.

Chart for Determining Head, Capacity, Efficiency, Horse Power With Any Three Conditions Known

(From the Peerless Pump Bulletin)

DELIVERY CAPACITY AND PRESSURE DROP THROUGH BRASS AND COPPER PIPE

This chart reveals the correct size of brass pipe or copper pipe or tubing to install for desired delivery of flow and residual pressure requirements.

Since the chart has been developed from reliable formulae, developed at Harvard University for straight runs of brass and copper pipes, it is necessary to allow something additional in the way of friction through valves, elbows and fittings. On this account, for the average service line it is good practice to add 20% to the actual length of run of pipe to compensate for loss of head through valves and fittings.

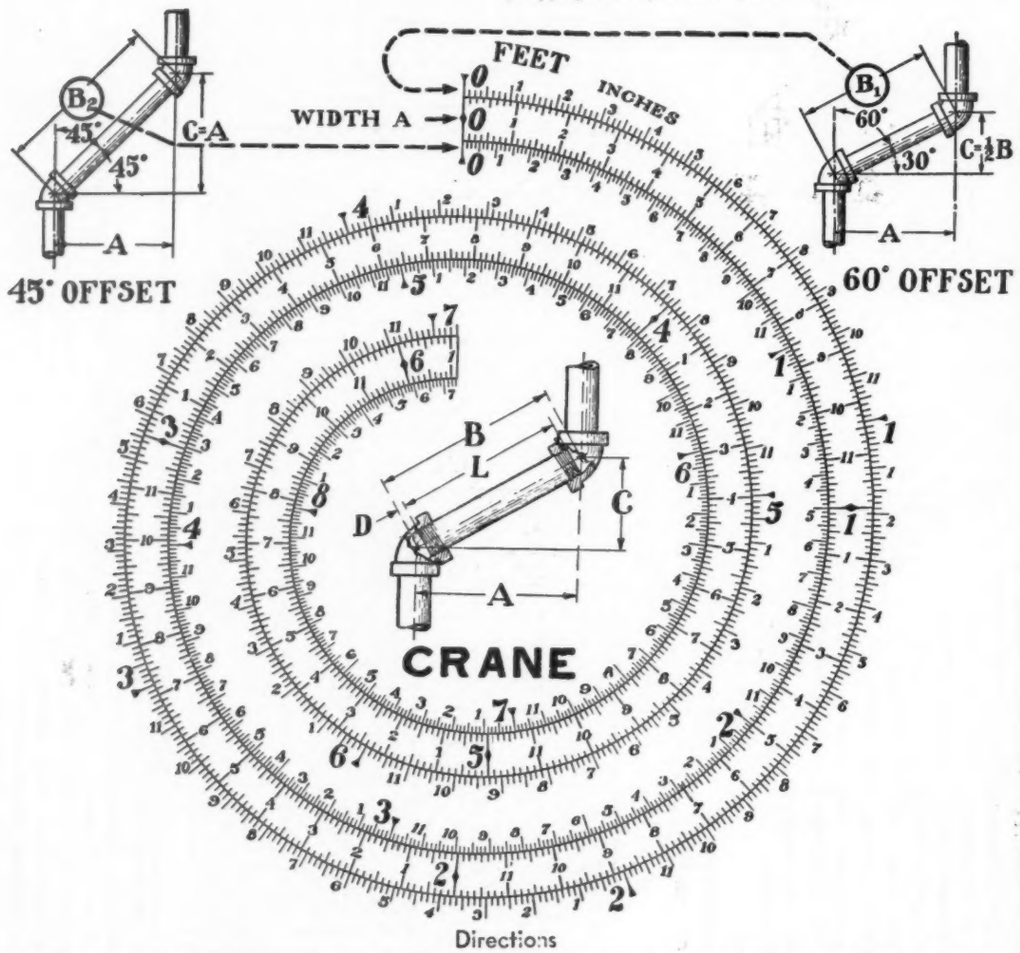
Example: There is an available pressure drop of 30 lbs., and the minimum delivery requirement at fixtures is 35 gals./ min. What size of pipe is required for this service?

Assume a run of 100 ft to compensate for fittings, etc., add the 20% to secure an "indicated" run of 120 ft. From the 120 ft. point on the base line run up to intersect the down slanting line representing 1 in. pipe; then to the right to the 30 lb. up slanting pressure line; then up to the G.P.M. line. The answer is 36 gals./min. If the ¾ in. size had been tried the result would have been only 17 gals./min. delivery with a 30 lb. pressure available at the main. On the other size an 1¼ in. line will deliver twice the requirement—i. e., 70 gals./min. Or, for the 35 gal. rate of delivery only 10 lbs. of pressure would be required.

It is evident, therefore, that the chart will reveal the proper size of pipe to deliver a required flow with any desired residual pressure at the outlet. In this case use the difference between the normal minimum pressure at the main and the residual pressure desired as the "available" pressure and proceed as in the example given.

OFFSET CHART FOR 45° & 60° SCREWED FITTINGS

(Copyrighted by Crane Co.)



Pipe size...	⅛"	¼"	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"
45° deduct.	.....	¾"	⅞"	¾"	1"	1⅛"	1⅜"	1⅝"	2"	2"	2⅜"
60° deduct.	.....	.....	.....	1"	1⅛"	1⅜"	1⅝"	2"	2⅜"	2½"	3"
Pipe size...	3½"	4"	4½"	5"	6"	7"	8"	9"	10"	12"	
45° deduct.	2⅝"	3⅛"	3⅜"	3¾"	4⅜"	5¼"	5⅞"	6⅝"	7⅜"	8¾"	
60° deduct.	.....	3⅞"	.....	4⅝"	5⅝"	6⅝"	9⅛"	.....	9⅛"	.....	

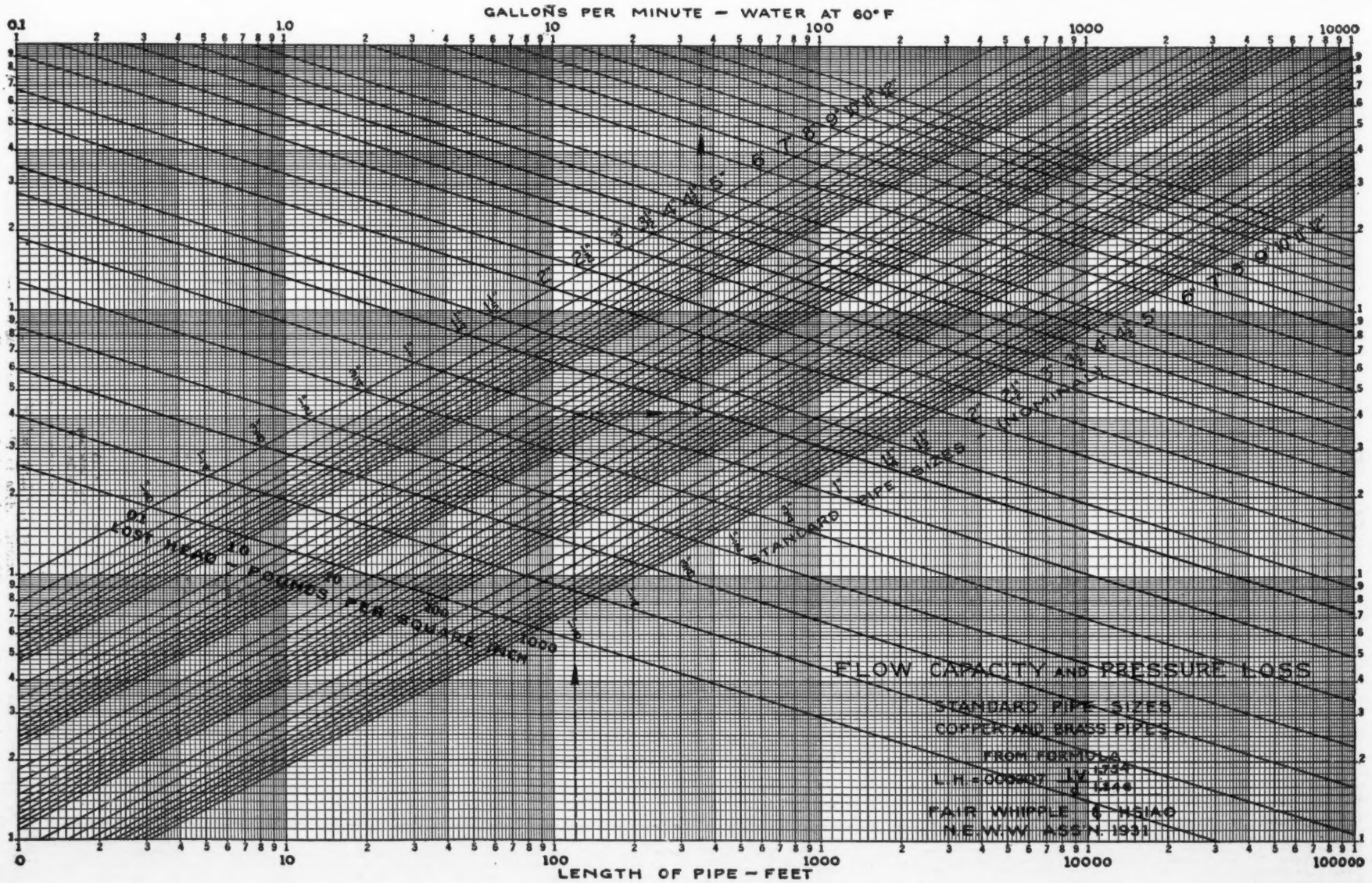
Note—The above figures represent 2xD. To find D divide by 2.

Directions

To determine the actual length of pipe, L, to use for length B, find in the table on right the amount to deduct for the desired pipe size and subtract it from length B.

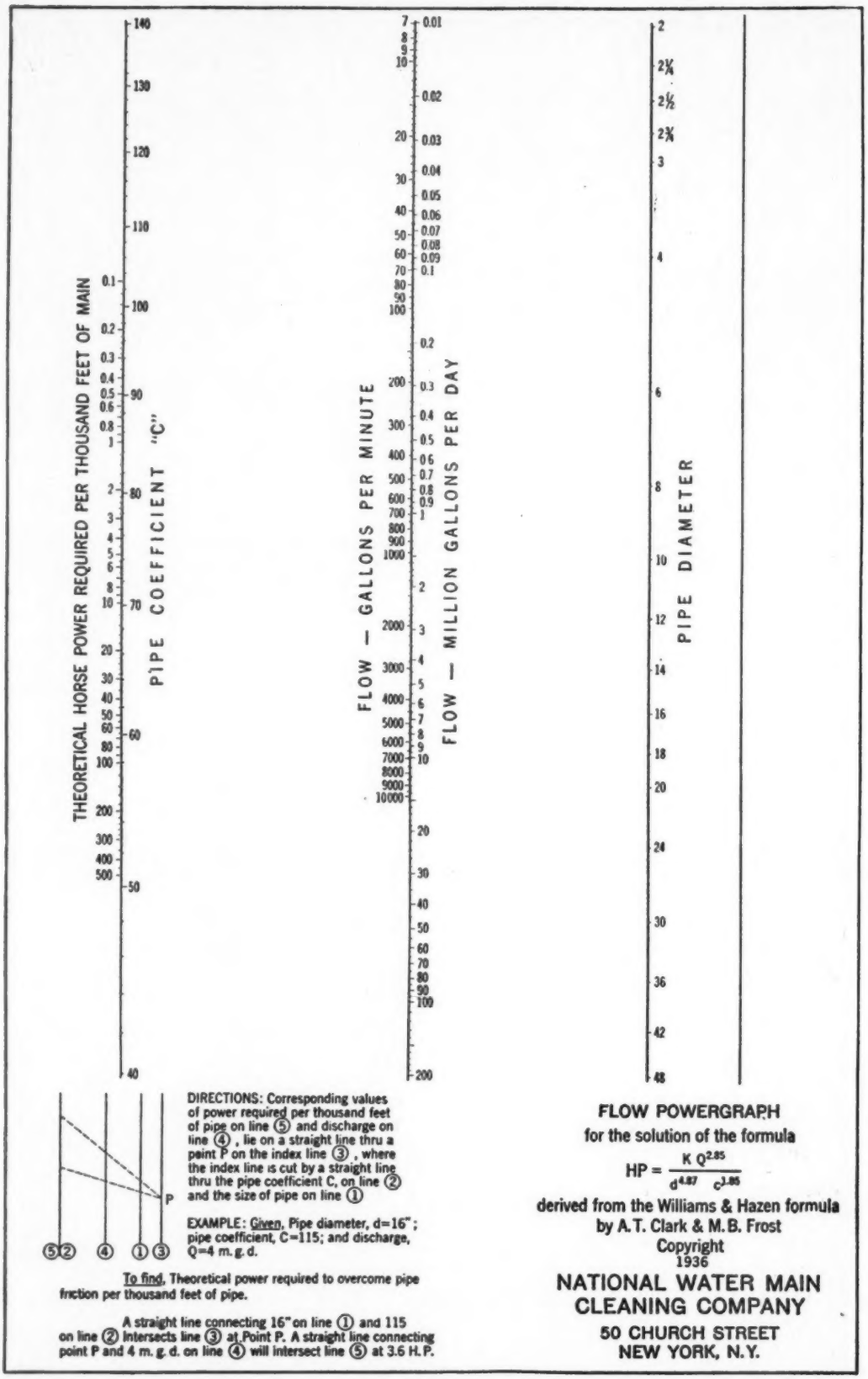
For example, using the above chart, a 45° offset of width 4′-2⅛″ (A) gives the length of run B as 5′-10⅞″ center to center. If it is a 2″ pipe then the table indicates the amount to deduct is 2″. Subtracting this from 5′-10⅞″ gives 5′-8 ⅛″ as the length of pipe to cut (L).

DELIVERY CAPACITY AND PRESSURE DROP THROUGH BRASS AND COPPER PIPE



A chart developed by the Brass and Copper Research Association from formulae established at Harvard University

Flow Powergraph


THEORETICAL HORSE POWER REQUIRED PER THOUSAND FEET OF MAIN
PIPE COEFFICIENT "C"
FLOW — GALLONS PER MINUTE
FLOW — MILLION GALLONS PER DAY
PIPE DIAMETER
DIRECTIONS: Corresponding values of power required per thousand feet of pipe on line ⑤ and discharge on line ④, lie on a straight line thru a point P on the index line ③, where the index line is cut by a straight line thru the pipe coefficient C, on line ② and the size of pipe on line ①
EXAMPLE: Given, Pipe diameter, d=16"; pipe coefficient, C=115; and discharge, Q=4 m.g.d.
To find, Theoretical power required to overcome pipe friction per thousand feet of pipe.
A straight line connecting 16" on line ① and 115 on line ② intersects line ③ at Point P. A straight line connecting point P and 4 m.g.d. on line ④ will intersect line ⑤ at 3.6 H.P.
FLOW POWERGRAPH
for the solution of the formula
HP = K Q^2.85 / d^4.87 C^1.85
derived from the Williams & Hazen formula
by A.T. Clark & M.B. Frost
Copyright
1936
NATIONAL WATER MAIN CLEANING COMPANY
50 CHURCH STREET
NEW YORK, N.Y.

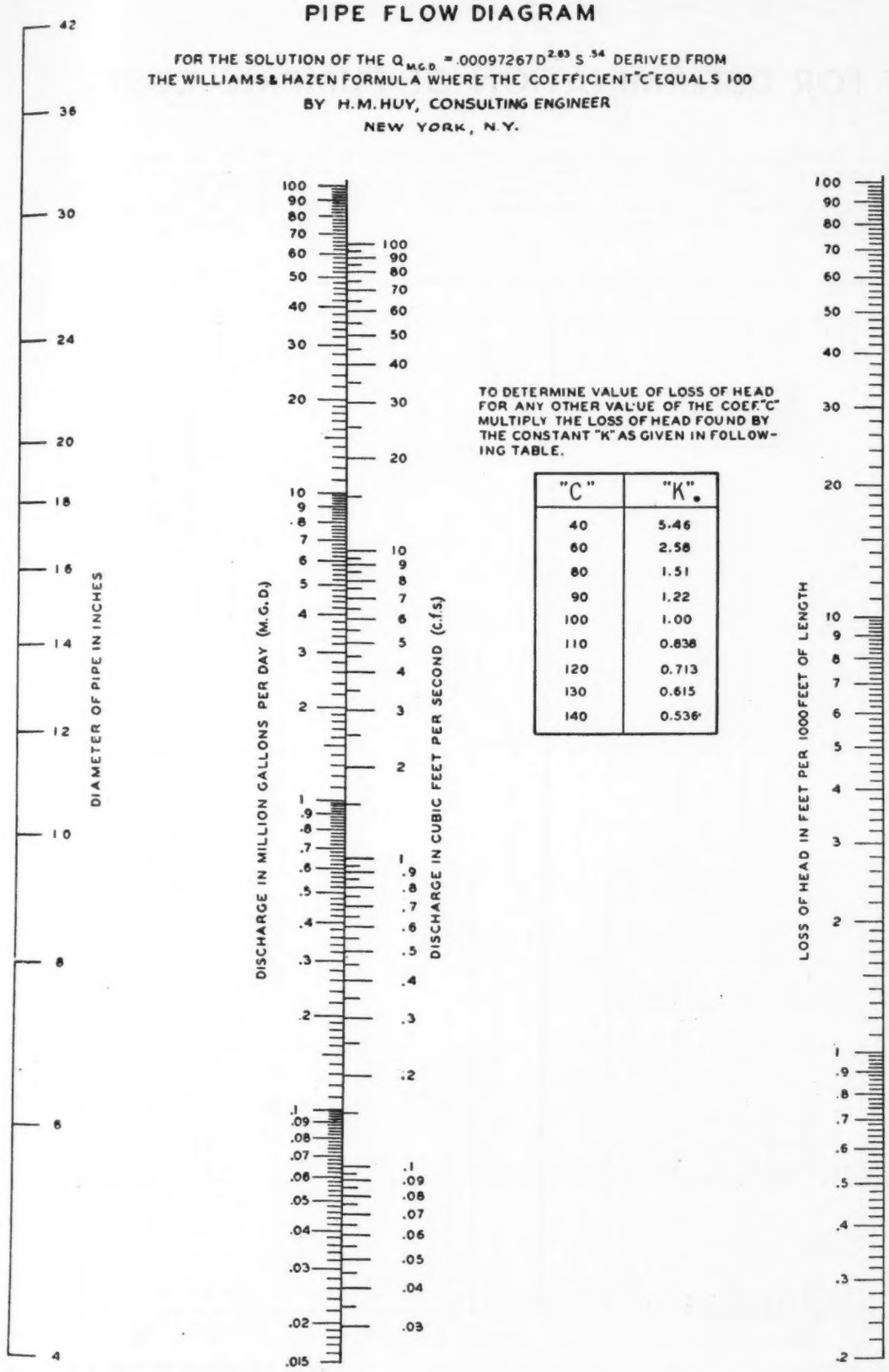
This Highly Useful Graph Was Devised by Arthur T. Clark and M. B. Frost for Simplified Determination of Power Required to Overcome Pipe Friction Under Various Conditions. Also to Determine Condition of Pipe Lines in Service. (Copies of This Graph on Linen Are Being Distributed Gratis by National Water Main Cleaning Co., New York City.)

PIPE FLOW DIAGRAM

FOR THE SOLUTION OF THE $Q_{M.G.D.} = .00097267 D^{2.63} S^{.54}$ DERIVED FROM THE WILLIAMS & HAZEN FORMULA WHERE THE COEFFICIENT "C" EQUALS 100

BY H. M. HUY, CONSULTING ENGINEER

NEW YORK, N.Y.



TO DETERMINE VALUE OF LOSS OF HEAD FOR ANY OTHER VALUE OF THE COEF. "C" MULTIPLY THE LOSS OF HEAD FOUND BY THE CONSTANT "K" AS GIVEN IN FOLLOWING TABLE.

"C"	"K".
40	5.46
60	2.58
80	1.51
90	1.22
100	1.00
110	0.838
120	0.713
130	0.615
140	0.536

(b) FRICTION COEFFICIENT "C": Determine hydrant discharge rate (M.G.D.) at the end of a section of pipe line. Take simultaneous pressure readings at non-flowing hydrants on the same line several hundred feet ahead. Correct all pressure readings for difference in elevations of gages and calculated friction head loss per 1,000 ft. of intervening pipe*. From flow rates observed and known pipe diameter, follow Example (a) to obtain loss of head which would have resulted with coefficient at "C100." This figure divided into the actual (observed) loss of head reveals the "K" factor and from the useful "C-K" table the coefficient "C" can be approximated. *(Accuracy depends upon use of tested pressure gages, careful flow measurements, and inducing a large loss of head between the non-flowing hydrants. For procedure in making hydrant flow tests, see article by Wilson elsewhere in this Section.)

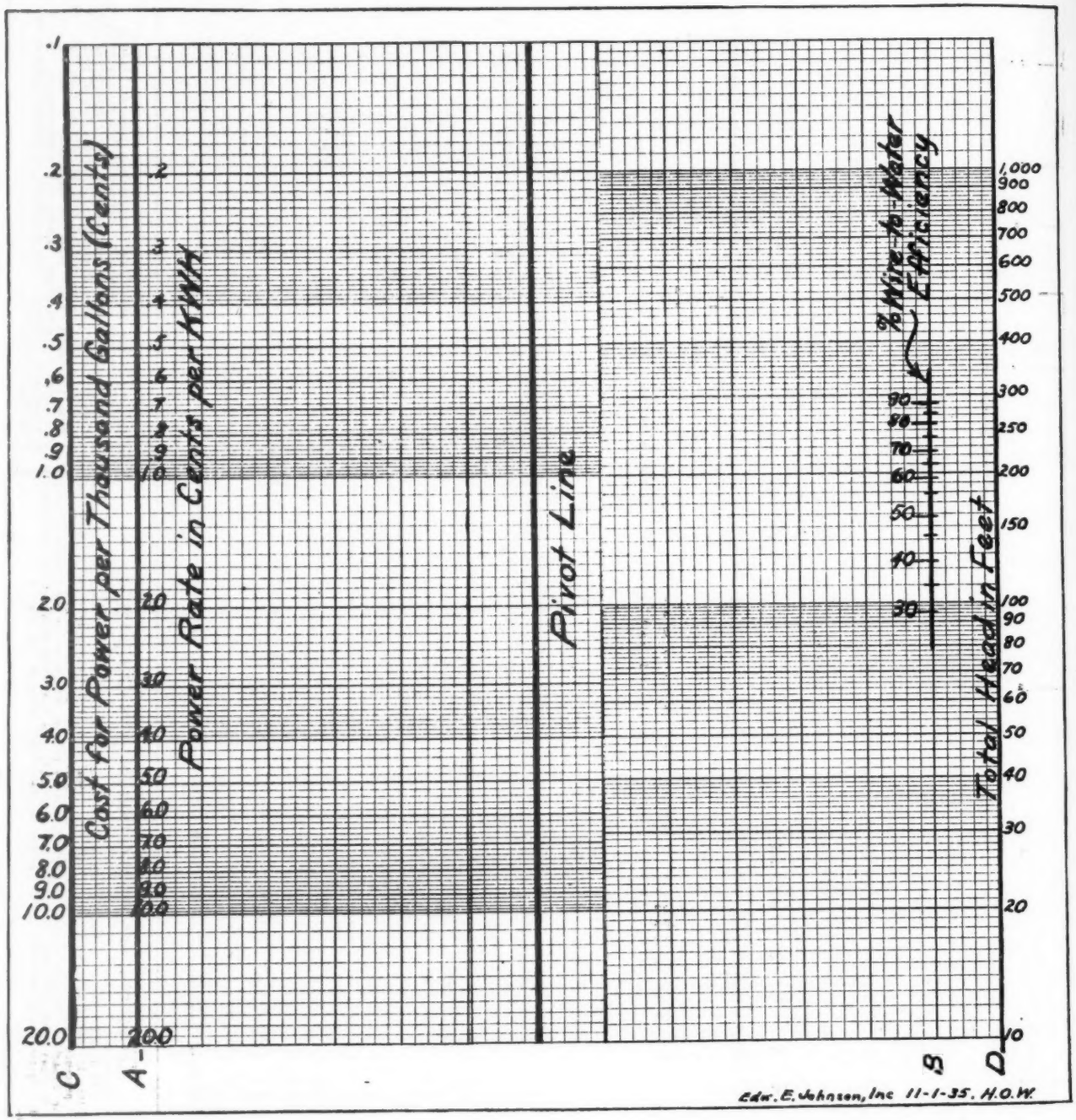
Directions for Application of This Diagram

(a) FRICTION-HEAD LOSS: A line run from pipe diameter (left vertical) through M.G.D. rates of flow (center) intersects friction vertical (right) to reveal computed friction loss per 1,000 ft. of pipe line; or pressure required per 1,000 ft., in pumping, to overcome such loss due to friction at corresponding line capacity. (If the friction coefficient due to greater roughness or smoothness of the pipe walls, is other than the base used ["C=100"] multiply the head loss obtained by the corresponding "K" factor given for various "C" values in the "C-K" table on the chart.)

(This diagram is reproduced through courtesy of H. M. Huy and permission of Hydraulic Development Corp. At a location earlier in this Data Section "Practical Methods of Making Flow Tests at Hydrants" are described by P. S. Wilson.)

CHART FOR DETERMINATION OF PUMPING COSTS

This chart is used for determining the power cost of pumping water per thousand gallons when the total head, wire-to-water efficiency and power rate are known. In using this chart a ruler is placed from line A (Power Rate in Cents per Kilowatt Hour) to line B (% Wire-to-Water Pump Efficiency). A pin or pencil point is placed against the edge of the ruler on the Pivot Line and the ruler is then pivoted to the proper point on line D (Total Head in Feet). The Cost for Power per Thousand Gallons can then be read directly from line C at the left of the chart. *(Courtesy Edward E. Johnson, Inc.)*

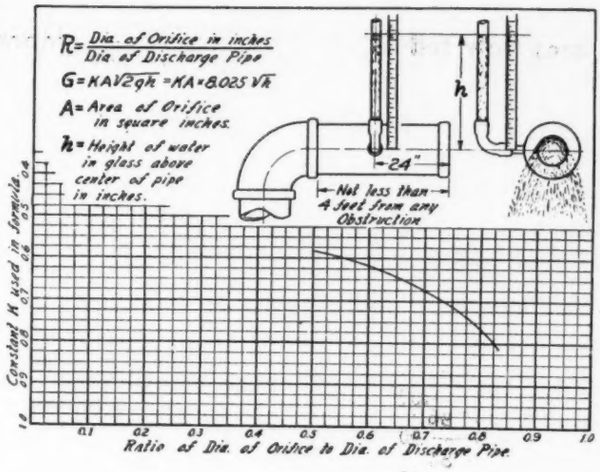


MEASURING FLOWS By THE ORIFICE METHOD

The orifice method is a simple way to measure flow of water from a pipe discharging horizontally into the open air. The sketch shows the general arrangement.

A plate or cap is affixed to the end of the pipe with the circular orifice in the exact center of the pipe. The size of orifice should be from one-half to three-quarters of the size of the pipe, but must be of such size that it will run full of water.

A hole for ⅛-in. pipe should be drilled and tapped 24 in. back from the orifice and a short ⅛-in. nipple screwed in until the inner end is exactly flush with the inner wall of the pipe. One end of a piece of rubber hose


R= Dia. of Orifice in inches / Dia. of Discharge Pipe
G=KAV2gh =KA×8.025 √h
A= Area of Orifice in square inches
h= Height of water in glass above center of pipe in inches.
h
24"
Not less than 4 feet from any Obstruction
Constant K used in formula
Ratio of Dia. of Orifice to Dia. of Discharge Pipe

is slipped over the end of the nipple and the other end over a glass tube, which should be supported in a vertical position.

Ratio R is the diameter of the orifice divided by the inside diameter of the pipe, and the proper value of K is found from the curve. In the formula A is figured as the area of the orifice in square inches, G = 32.2, and H is read as the height in inches of the water in the glass tube above the center of the pipe. Gallons per minute (g) then can be figured.

For convenience when determining capacities during pumping tests, the accompanying table for various orifices commonly employed will prove useful.

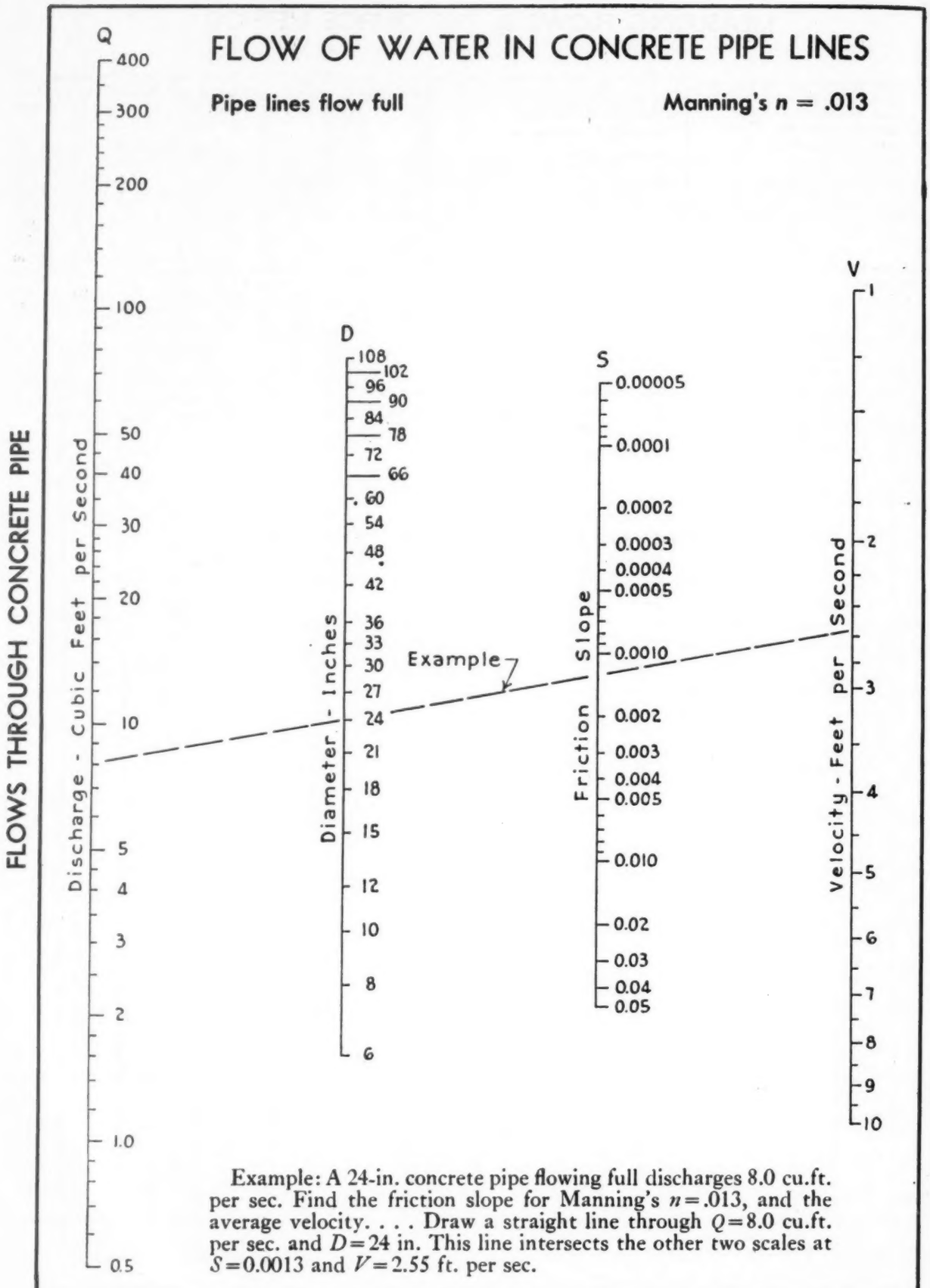
ORIFICE TABLE FOR DETERMINING WATER FLOW

[Compiled by the Engineering Department of Layne and Bowler, Inc., from original calibrations made in the Hydraulics Laboratories at Purdue University.]

Head in Inches	3" Orifice		4" Orifice		5" Orifice		6" Orifice		7" Orifice	8" Orifice	Head in Inches
	4 in. Pipe	6 in Pipe	6 in. Pipe	8 in. Pipe	6 in. Pipe	8 in. Pipe	8 in. Pipe	10 in. Pipe	10 in. Pipe	10 in. Pipe	
5	100	76	145	140	280	220	380	320			5
5.5	104	79	153	145	293	230	394	333			5.5
6	108	82	160	150	305	240	408	345			6
6.5	111	85	167	155	316	250	421	358			6.5
7	115	88	172	160	328	260	433	370			7
7.5	119	91	179	165	339	270	446	383			7.5
8	122	94	185	170	350	280	458	395	600	935	8
8.5	125	96	190	175	361	289	471	408	617	963	8.5
9	128	99	195	180	372	298	483	420	633	992	9
9.5	130	102	200	185	383	307	495	433	650	1016	9.5
10	133	104	205	190	393	316	508	445	666	1040	10
10.5	137	107	210	195	402	324	521	458	682	1060	10.5
11	140	109	215	200	412	330	533	470	698	1080	11
11.5	143	111	220	204	421	338	545	480	713	1100	11.5
12	146	114	225	208	430	346	556	490	728	1120	12
12.5	149	116	230	212	439	354	567	500	743	1139	12.5
13	151	118	234	216	448	362	578	510	757	1158	13
13.5	154	121	239	219	457	369	589	520	771	1176	13.5
14	157	123	243	224	465	376	599	530	785	1194	14
14.5	159	126	247	227	473	383	609	540	799	1212	14.5
15	162	128	250	231	480	390	618	550	812	1230	15
15.5	164	130	254	234	488	396	627	559	825	1248	15.5
16	167	132	257	238	495	402	636	568	838	1266	16
16.5	170	134	261	241	503	408	645	577	851	1284	16.5
17	172	136	264	245	510	414	654	586	863	1302	17
17.5	175	138	268	249	517	420	663	595	875	1319	17.5
18	178	140	271	252	524	426	672	604	887	1336	18
18.5	180	142	275	256	530	432	681	612	899	1353	18.5
19	183	144	278	259	536	438	690	620	910	1370	19
19.5	185	146	282	263	542	444	699	628	922	1387	19.5
20	187	148	285	266	548	449	708	636	933	1404	20
20.5	190	150	289	270	554	455	717	643	945	1421	20.5
21	192	152	292	273	560	460	726	650	956	1438	21
21.5	195	154	295	275	566	465	735	657	968	1455	21.5
22	197	156	299	279	572	470	744	664	979	1471	22
22.5	199	158	302	282	578	475	752	671	990	1486	22.5
23	201	160	305	285	584	479	760	678	1001	1500	23
23.5	203	162	307	288	590	484	768	685	1012	1515	23.5
24	205	164	310	291	596	488	776	692	1022	1529	24
24.5	207	165	314	294	602	492	784	699	1033	1543	24.5
25	210	167	317	297	608	496	791	706	1043	1557	25
25.5	212	169	320	300	614	500	798	713	1059	1571	25.5
26	214	171	323	303	620	504	805	720	1064	1585	26
26.5	216	173	326	305	626	508	812	727	1074	1599	26.5
27	219	174	329	308	632	512	818	734	1084	1613	27
27.5	221	176	332	311	638	516	825	741	1094	1627	27.5
28	222	177	335	314	644	520	831	747	1104	1641	28
28.5	224	179	337	317	650	524	838	754	1114	1655	28.5
29	226	180	340	320	656	528	844	760	1124	1669	29
29.5	228	182	343	323	662	532	851	767	1134	1683	29.5
30	230	183	346	325	668	536	857	773	1143	1697	30
30.5	232	185	348	328	674	540	863	780	1153	1711	30.5
31	235	186	351	330	680	544	869	786	1162	1725	31
31.5	236	188	354	333	686	548	876	793	1172	1739	31.5
32	239	189	357	335	692	552	882	799	1181	1753	32
32.5	240	191	360	338	697	556	889	806	1191	1767	32.5
33	242	192	363	340	703	560	895	812	1200	1791	33
33.5	244	194	366	342	709	564	901	818	1209	1795	33.5
34	246	195	369	345	715	568	907	824	1218	1809	34
34.5	248	196	372	347	720	572	913	830	1227	1823	34.5
35	250	197	375	349	726	576	919	836	1235	1837	35
35.5	252	198	377	351	732	580	925	842	1243	1851	35.5
36	254	200	380	354	737	584	931	847	1251	1865	36

Head in Inches	3" Orifice		4" Orifice		5" Orifice		6" Orifice		Head in Inches
	4 in. Pipe	6 in. Pipe	6 in. Pipe	8 in. Pipe	6 in. Pipe	8 in. Pipe	8 in. Pipe	10 in. Pipe	
36.5	256	201	383	356	743	588	937	852	36.5
37	257	203	385	358	748	592	943	857	37
37.5	259	204	388	360	754	596	949	862	37.5
38	260	205	390	363	759	600	955	867	38
38.5	262	206	393	365	765	604	961	872	38.5
39	263	208	396	367	770	608	967	877	39
39.5	265	209	398	369	776	612	974	882	39.5
40	266	210	401	371	781	616	979	887	40
40.5	267	211	403	373	786	620	985	891	40.5
41	269	212	406	375	790	624	990	896	41
41.5	271	213	408	378	795	628	996	901	41.5
42	272	214	411	380	800	631	1001	906	42
42.5	274	216	413	382	805	635	1007	910	42.5
43	275	217	415	384	810	638	1012	915	43
43.5	277	218	418	386	815	642	1018	920	43.5
44	278	219	420	388	820	645	1023	925	44
44.5	280	220	422	390	824	649	1029	929	44.5
45	281	222	425	392	828	652	1034	934	45
45.5	283	223	427	394	832	656	1040	939	45.5
46	284	224	429	396	837	659	1045	944	46
46.5	285	225	432	399	842	663	1051	948	46.5
47	287	227	434	401	847	666	1056	953	47
47.5	289	228	437	403	851	669	1062	958	47.5
48	290	229	440	405	855	672	1067	963	48
48.5	292	230	442	407	859	676	1073	967	48.5
49	293	231	444	409	863	679	1078	972	49
49.5	294	232	446	411	868	683	1084	977	49.5
50	296	234	448	413	872	686	1089	982	50
50.5	298	235	450	415	876	690	1095	986	50.5
51	300	236	453	417	880	693	1100	991	51
51.5	301	237	455	419	884	697	1105	996	51.5
52	302	238	457	421	888	700	1110	1000	52
52.5	303	239	459	423	892	704	1115	1005	52.5
53	304	240	461	425	896	707	1120	1009	53
53.5	305	241	463	427	900	711	1125	1014	53.5
54	307	243	465	429	904	714	1130	1018	54
54.5	309	244	467	431	908	718	1135	1023	54.5
55	310	246	469	433	912	721	1140	1027	55
55.5	311	247	471	435	915	725	1145	1032	55.5
56	313	248	472	437	919	727	1150	1036	56
56.5	314	249	474	439	923	730	1155	1040	56.5
57	315	250	476	441	927	733	1160	1044	57
57.5	316	251	478	443	930	736	1165	1046	57.5
58	317	252	480	445	934	739	1170	1052	58
58.5	319	253	482	447	938	742	1175	1056	58.5
59	320	254	485	449	942	745	1180	1060	59
59.5	321	256	487	451	945	748	1185	1064	59.5
60	323	257	489	453	948	751	1190	1068	60
60.5	324	258	491	455	951	754	1195	1072	60.5
61	325	259	492	457	955	757	1200	1076	61
61.5	326	261	494	459	958	760	1205	1080	61.5
62	328	262	496	461	961	763	1209	1084	62
62.5	329	263	498	463	964	766	1214	1088	62.5
63	330	264	500	465	968	769	1218	1092	63
63.5	331	265	502	467	971	772	1223	1096	63.5
64	333	266	504	469	974	775	1227	1099	64
64.5	334	267	507	471	977	778	1232	1103	64.5
65	335	268	509	472	981	781	1236	1106	65
65.5	336	269	511	474	984	784	1241	1110	65.5
66	338	271	513	475	988	787	1245	1113	66
66.5	339	272	515	477	991	790	1250	1117	66.5
67	340	273	517	479	995	793	1254	1120	67
68	343	275	520	483	1002	799	1263	1127	68
70	349	280	525	491	1016	811	1280	1140	70

Courtesy of Layne & Bowler, Inc.

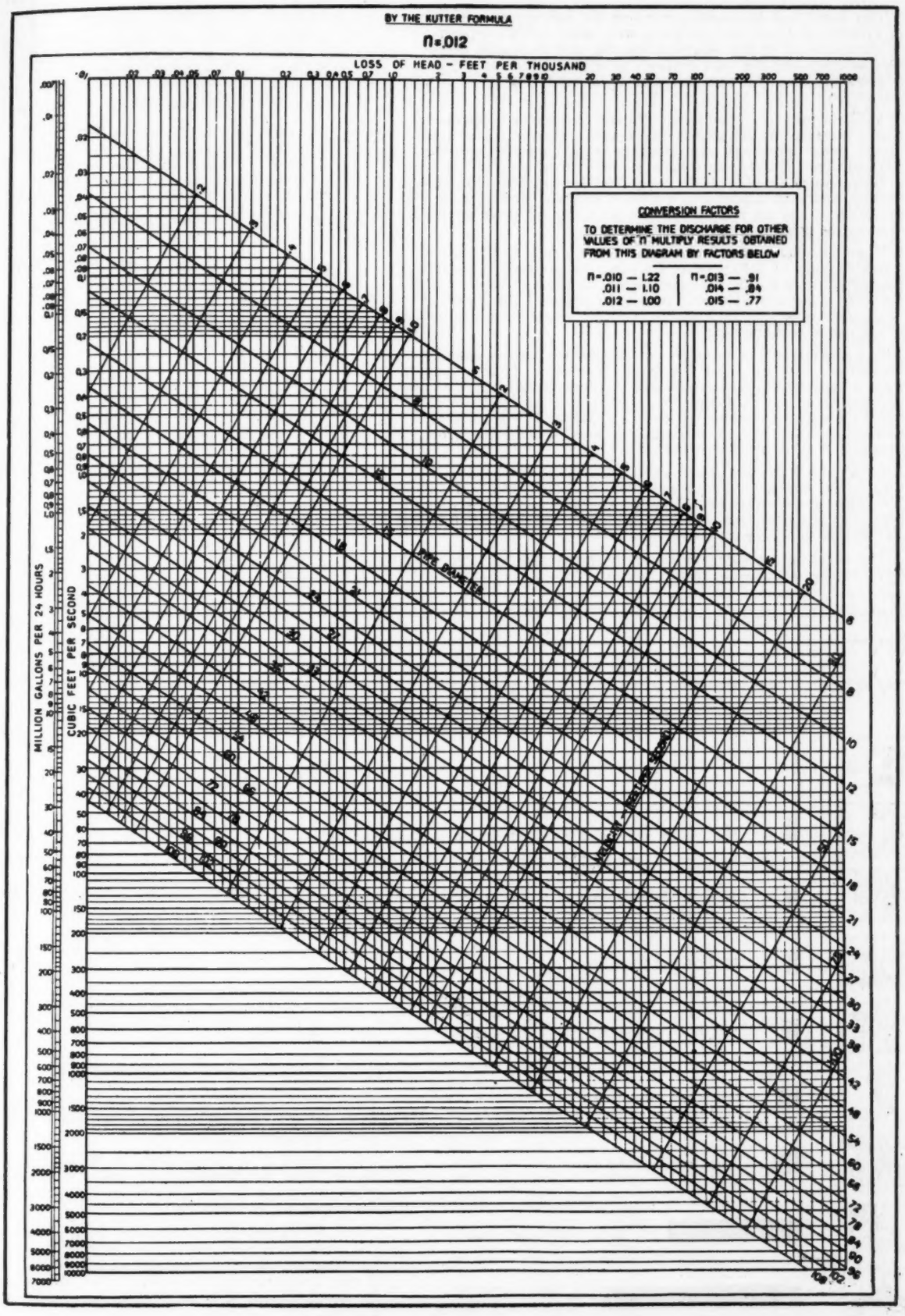


Example: A 24-in. concrete pipe flowing full discharges 8.0 cu.ft. per sec. Find the friction slope for Manning's $n=.013$, and the average velocity. . . . Draw a straight line through $Q=8.0$ cu.ft. per sec. and $D=24$ in. This line intersects the other two scales at $S=0.0013$ and $V=2.55$ ft. per sec.

A chart constructed by Dr. F. T. Mavis, head Dept. of Civil Engineering, Penna. State College and appearing with the chapter "Flow of Water In Pipe Lines" by Professor J. E. Christiansen, University of California, written for "Concrete Pipe Lines," published by the American Concrete Pipe Association, 1942.

**Methods of constructing this type of chart are explained in detail in "The Construction of Nomographic Charts," by F. T. Mavis. Published by International Textbook Company, Scranton, Pa., 1939.*

FLOWS THROUGH CONCRETE PIPE


BY THE KUTTER FORMULA
n=.012
LOSS OF HEAD - FEET PER THOUSAND
MILLION GALLONS PER 24 HOURS
CUBIC FEET PER SECOND
PIPE DIAMETER
VELOCITY - FEET PER SECOND
CONVERSION FACTORS
TO DETERMINE THE DISCHARGE FOR OTHER VALUES OF n MULTIPLY RESULTS OBTAINED FROM THIS DIAGRAM BY FACTORS BELOW
n=.010 — 1.22
.011 — 1.10
.012 — 1.00
n=.013 — .91
.014 — .84
.015 — .77

A graph developed by N. D. Whitman, late Consulting Engineer of Los Angeles, appearing in "Concrete Pipe Lines," published by the American Concrete Pipe Association in 1942.

HYDRAULIC POWER-LIFT CHART*

This chart will be found convenient for solving a multitude of cylinder problems in connection with water plant machinery. It eliminates all of the longhand figuring that is usually necessary in computing the total pressure on a piston, the capacity of a pressure hoist, the pressure needed to achieve a given lift, and so on.

Thus, for instance, if you have a cylinder that is 6 in. in diameter and a pressure of 100 pounds per square inch, the dotted line drawn across this chart connecting the 6 in column A with the 100 in column C shows in column B that the cylinder will have a lifting capacity of a trifle over 2500 pounds. Thus, simply connect the known diameter in column A with the known pressure in column C and the intersection through column B gives the lift capacity in pounds.

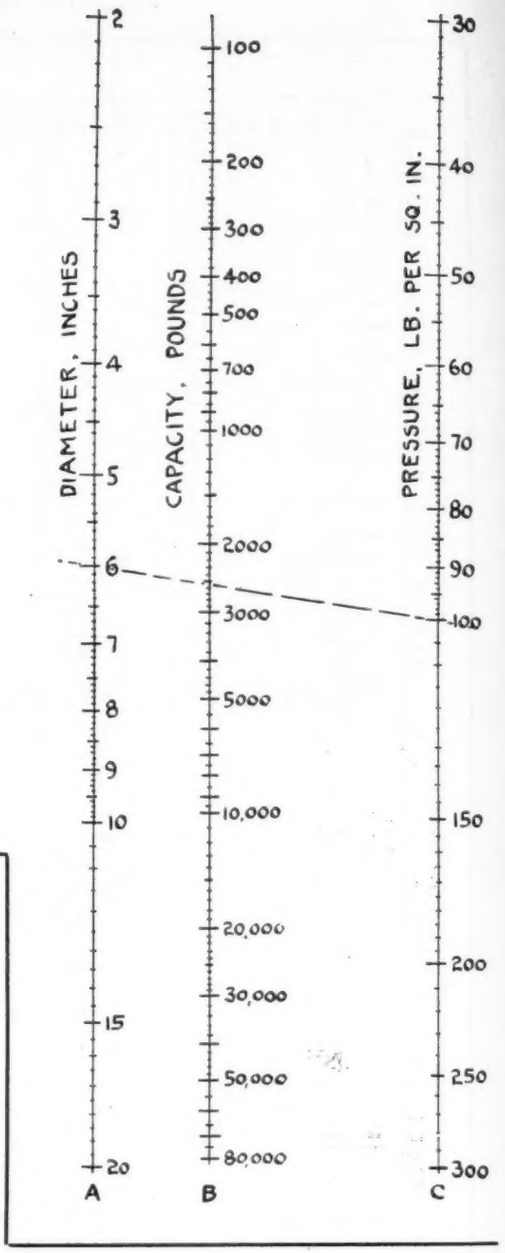
If, on the other hand, it is desired to choose a cylinder to provide a life capacity of 2500 pounds, knowing the pressure to be 100 pounds per square inch, the same dotted line gives a diameter of 6 in. Or, if the available head is only 50 pounds a line from 50 (Col. C) through the 2500 pounds (Col. B) reveals that a piston of 8.5 inches is required.

Run a straight line through any two known factors and the intersection with the third line gives the answer. Thus, if you want a capacity of 2500 pounds and you have a cylinder whose diameter is only 6 in. a pressure of 100 pounds per square inch will be needed to produce the desired capacity. If you have an 8-in. cylinder then the pressure need be but 55 pounds—line from 8 in Col. A through 2500 in Col. B.

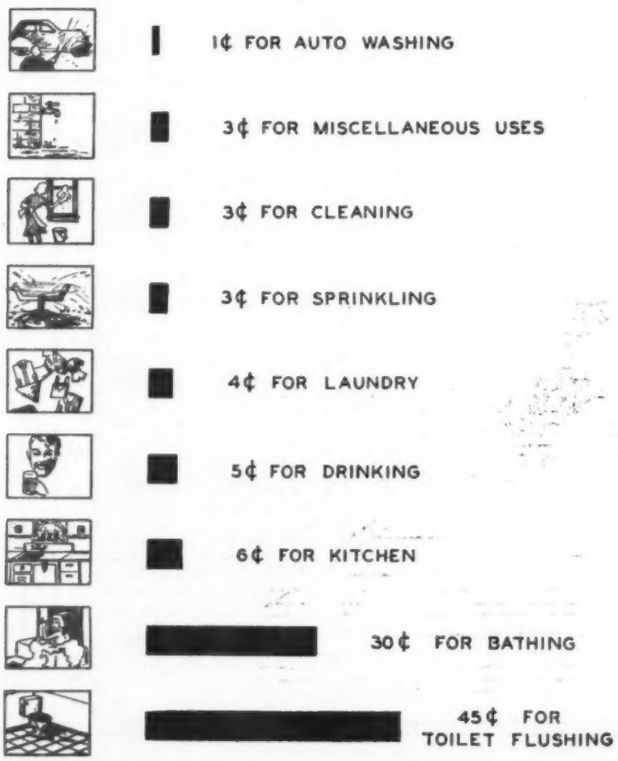
As will be noted, the chart has a great enough range to take care of any ordinary requirements, the diameters ranging from 2 to 20 in. and the pressures from 30 to 300 pounds per square inch. The lift capacities (Column B) range all the way from 100 pounds to 80,000 pounds, or 40 tons.

The graph is applicable to all of the fluids that are used in work of this nature—air, water, oil, etc.

*Contributed by W. F. Schaphorst.



WHERE THE WATER DOLLAR GOES



Here is an interesting and enlightening chart taken from the 22nd Annual Report of the Water Department, Springfield, Ill.

It is based on a survey made by H. V. Pedersen, Water Supt., at Marshalltown, Iowa, to determine what percentage of water in the average consumer's home goes for various uses.

The Springfield folks have taken these percentages and made them more real to the customer, by showing him that out of every dollar paid for water used it only cost him 1 cent to wash his car, only 4 cents for laundry work at home, 3 cents for sprinkling in summer.

HOW TO COMPARE PUMP EFFICIENCIES*

IF the efficiency of your present pump is 74% and you are planning to install a new pump whose efficiency will be 85%, the improvement will not be merely 11%. There will be an improvement of 13% in efficiency.

It is not uncommon for users and prospective users to subtract the efficiency of the old pump from that of the new one and call the difference the "improvement" in efficiency, but that is not correct. The correct method is to subtract the two efficiencies and then divide the difference by the efficiency of the new pump.

Thus, for example:

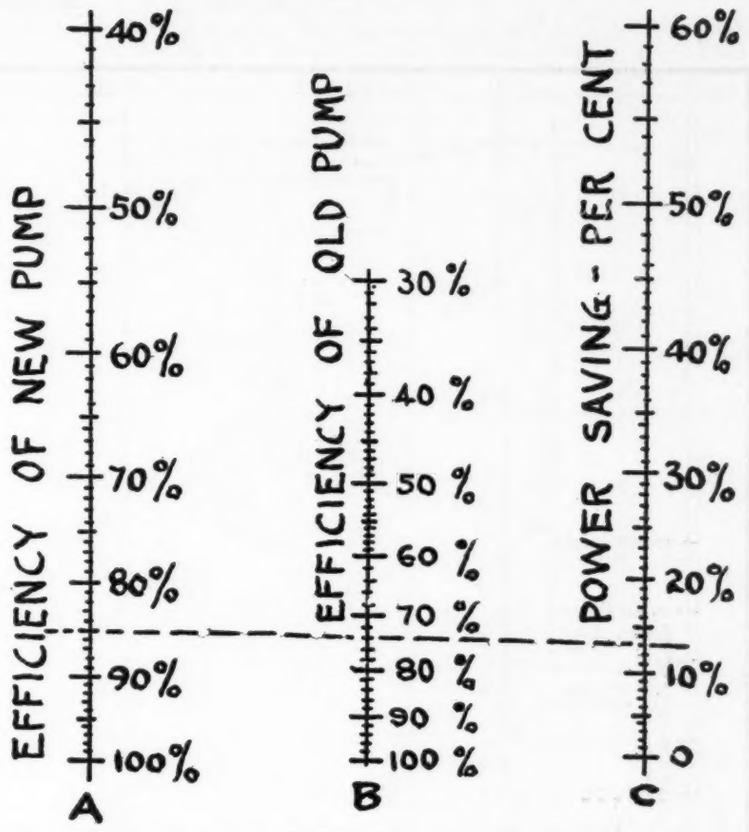
$$0.85 - 0.74 = 0.11$$
$$0.11 \div 0.85 = 0.13$$

which verifies the figures given above.

Let us suppose that you have a pump whose efficiency is only 40% and you are contemplating the installation of one whose efficiency will be 80%. The difference between the two efficiencies is 40%, but that is not the correct improvement. The true improvement is 40% ÷ 80% = 50%.

Herewith is a chart that gives the true improvement or "power saving" without any longhand figuring whatever. Simply run a straight line through the efficiency of the new pump, column A, and the efficiency of the old pump, column B, and the power saving or improvement in efficiency is instantly given in column C. Thus the dotted line drawn across this chart shows that where the efficiency of the new pump is 85% and that of the old pump is 74%, the true improvement which can be expected in power saving is 13%.

*Contributed by W. F. Schaphorst, M. E.



HORSE-POWER AND ELECTRICAL DATA

(a) 1 H.P. = 0.746 KW. = 746 watts.

(b) Brake H.P. $= \dfrac{\text{KW. input}}{0.746} \times$ motor efficiency.

(c) Water H.P. $= \dfrac{\text{g.p.m.} \times \text{head in ft.}}{3960}$.

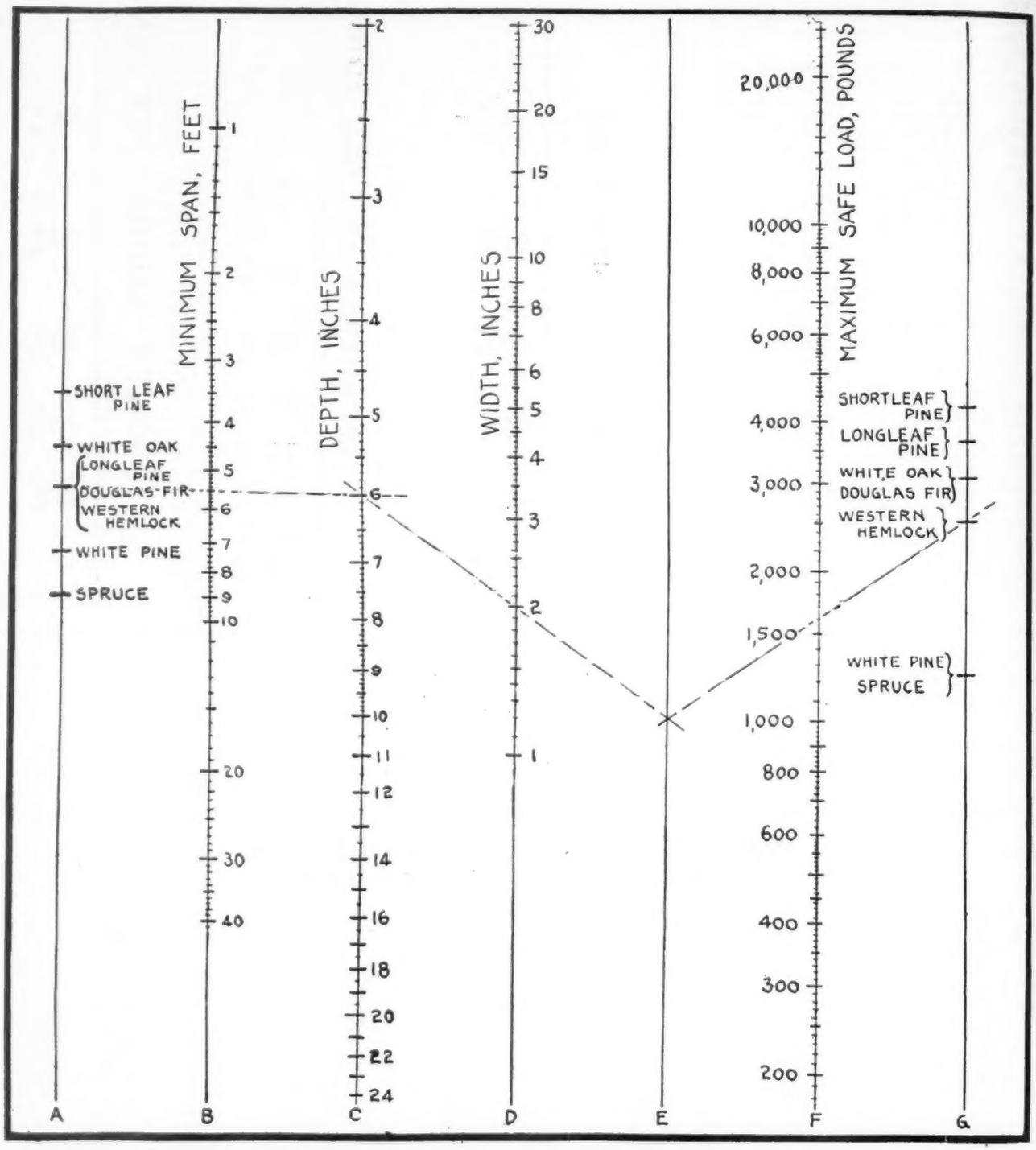
(d) H.P. to lift water $= \dfrac{\text{g.p.m.} \times \text{head in ft.}}{3960 \times \text{pump efficiency.}}$

PRESSURE IN POUNDS PER SQUARE INCH FOR DFFERENT HEADS OF WATER

Head In Feet	0	1	2	3	4	5	6	7	8	9
0	....	.43	.87	1.30	1.73	2.16	2.60	3.03	3.46	3.90
10	4.33	4.76	5.20	5.63	6.06	6.50	6.93	7.36	7.79	8.23
20	8.66	9.09	9.53	9.96	10.39	10.83	11.26	11.69	12.12	12.56
30	12.99	13.42	13.86	14.29	14.72	15.16	15.59	16.02	16.45	16.89
40	17.32	17.75	18.19	18.62	19.05	19.49	19.92	20.35	20.78	21.22
50	21.65	22.08	22.52	22.95	23.38	23.82	24.25	24.68	25.11	25.55
60	25.98	26.41	26.85	27.28	27.71	28.15	28.58	29.01	29.44	29.88
70	30.31	30.74	31.18	31.61	32.04	32.48	32.91	33.34	33.77	34.21
80	34.64	35.07	35.51	35.94	36.37	36.81	37.24	37.67	38.10	38.54
90	38.97	39.40	39.84	40.27	40.70	41.14	41.57	42.00	42.44	42.87
100	43.30	43.74	44.17	44.60	45.03	45.47	45.90	46.33	46.77	47.20
110	47.63	48.07	48.50	48.93	49.36	49.80	50.23	50.66	51.10	51.53
120	51.96	52.40	52.83	53.26	53.69	54.13	54.56	54.99	55.43	55.86
130	56.29	56.73	57.16	57.59	58.02	58.46	58.89	59.32	59.76	60.20
140	60.62	61.06	61.49	61.92	62.35	62.79	63.22	63.65	64.09	64.52
150	64.95	65.39	65.82	66.25	66.69	67.12	67.55	67.98	68.42	68.85
160	69.28	69.72	70.15	70.58	71.02	71.45	71.88	72.31	72.75	73.18
170	73.61	74.05	74.48	74.91	75.35	75.78	76.21	76.64	77.08	77.51
180	77.94	78.38	78.81	79.24	79.68	80.11	80.54	80.97	81.41	81.84
190	82.27	82.71	83.14	83.57	84.01	84.43	84.87	85.30	85.74	86.17
200	86.60	87.04	87.47	87.90	88.33	88.77	89.20	89.63	90.07	90.50

SAFE LOADINGS FOR WOODEN BEAMS

Contributed by W. F. Schaphorst, M.E.



THE above chart will be found handy for many purposes—in the selection of safe beams made of ordinary woods such as shortleaf white pine, white oak, longleaf pine, Douglas fir, western hemlock, white pine, and spruce. The chart is based on data adopted by the American Railway Engineering Association for safe, uniformly loaded wooden beams of rectangular section.

Example: It is desired to hold 200 lb. per foot on a wooden beam of 2 in. by 6 in. western hemlock over a span of 5 ft. Will the beam be safe?

Run a straight line from the point in column A opposite "western hemlock" over to the depth 6 in column C. The intersection with column B shows the minimum span to be 5.5 ft. The beam will therefore be safe as regards span.

Then from the depth 6 in column C run a straight line through

the width 2 in column D and locate the intersection in column F. Then from that point of intersection run a straight line over to the point in column G opposite "western hemlock." The answer is found at the intersection with column F and is 1,600 pounds.

Since it is desired to hold only 5×200 or 1000 lb. on the 5 ft. beam, and since the beam will actually hold 1,600 lb., it certainly is amply safe. In fact, the chart shows that a beam made of white pine or spruce would be safe under this load.

Inversely, the chart may be used for finding any unknown factor or factors. If the kind of wood and the span are known, the first straight line through columns A, B and C gives the minimum depth of beam which must be used. If the width of beam is unknown, the line through the columns E, F, G is located next, and lastly the line through columns C, D, E gives the minimum width of beam in column D.

The weight of the beam itself is included in the safe load given in column F, hence the user of the chart need not worry about that factor.

SAFE LOADINGS FOR I-BEAMS

Contributed by W. F. Schaphorst, M.E.

THE accompanying chart reveals how much any ordinary I-Beam will hold under the very *worst* condition, with the load concentrated in the middle of the span as shown by the sketch on the chart. The chart, for the sake of safety, is based on concentrated loading.

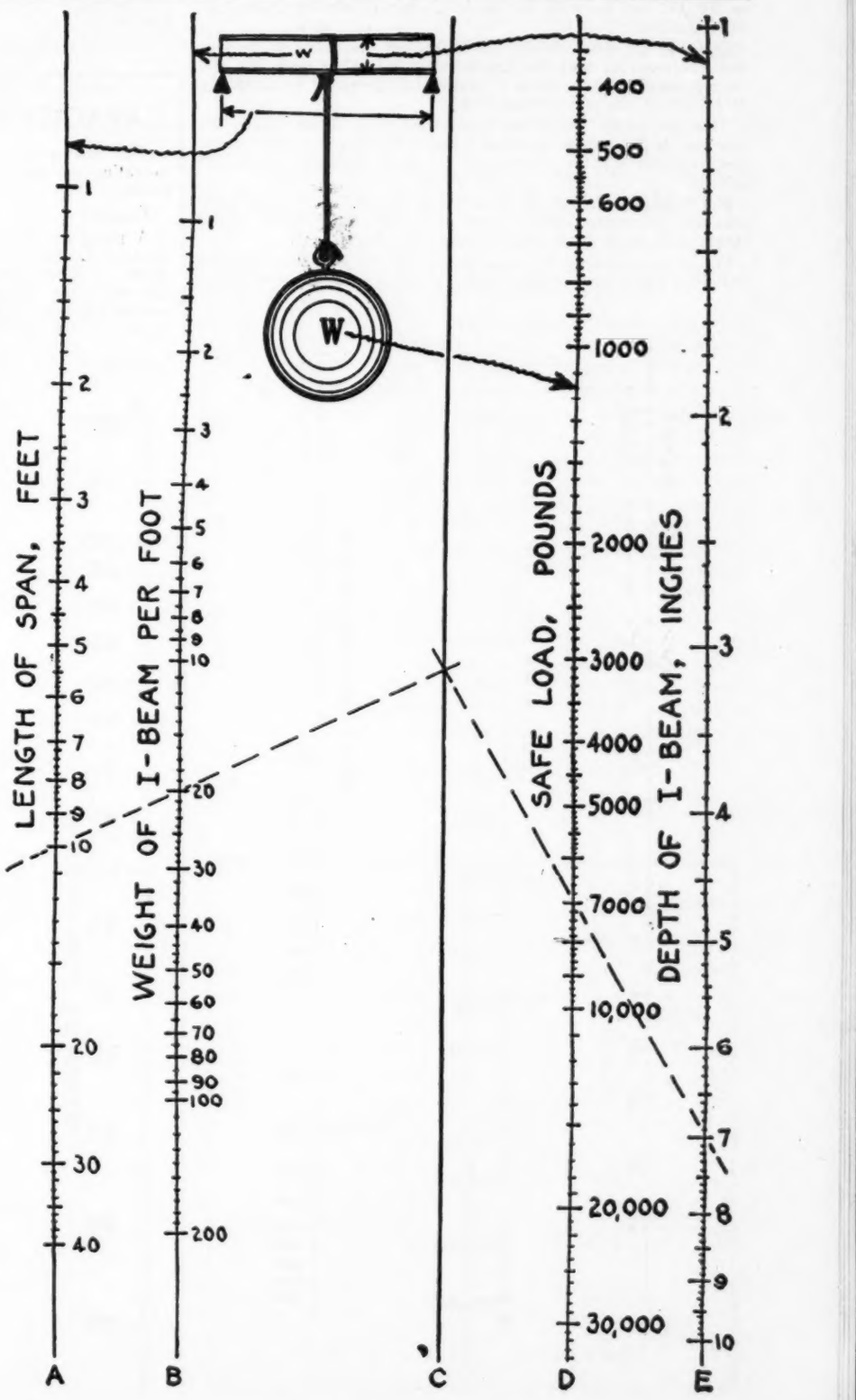
Let us suppose that a weight of 4,000 lbs. must be supported. A 7-inch I-Beam, weighing 240 lbs., is available. It is 12 feet long, and therefore weighs 20 lbs. per foot. The minimum distance between supports that can be obtained for the lifting operation is 10 feet. Is the I-Beam strong enough to lift the 4,000-lb. load?

The Answer

Run a straight line through the 10-ft. (column A) and the 20-lb. (column B) and locate the intersection in column C. Then, from that intersection in column C, run over to the 7-in. (column E). The intersection through column D shows that the I-Beam will support 7,000 lbs. Since the load to be lifted is only 4,000 lbs. the beam is amply strong. In fact, the reader can easily find, by applying the chart, that a 4-inch I-Beam, all other conditions being the same, would safely support the load of 4,000 lbs.

Similarly, it is easy to ascertain the maximum allowable span when the factors in columns B, D and E are known. Or, the necessary weight per foot of I-Beam may be determined when the factors in columns A, D and E are known. Lastly, the depth of beam is determinable when the factors in column A, B and D are known.

For loads that are "uniformly distributed"—not concentrated—the safe loads in column D may be multiplied by two. Thus, the above described beam will support a uniformly distributed load of 14,000 lbs., or 1,400 lbs. per running foot.



GALLONS IN WATER SUPPLY PIPE*

Water supply men often want to know the volume of a given length of pipe in gallons. This writer does not know of any table that gives such values and where volumes are to be found they are usually given in cubic feet. Besides, the range of a table is seldom great enough to cover all desired conditions.

This chart takes care of all standard pipe sizes from ⅛ inch to 15 inches on scale A, and any length of pipe line from 0.1 foot to 800,000 feet on scale B. Scale C shows volumes from 1 to 1,000 gallons.

In using the chart simply run a straight line through the pipe size (column A) and the length of pipe line (column B) and the intersection with column C immediately gives the total number of gallons in the pipe or pipe line.

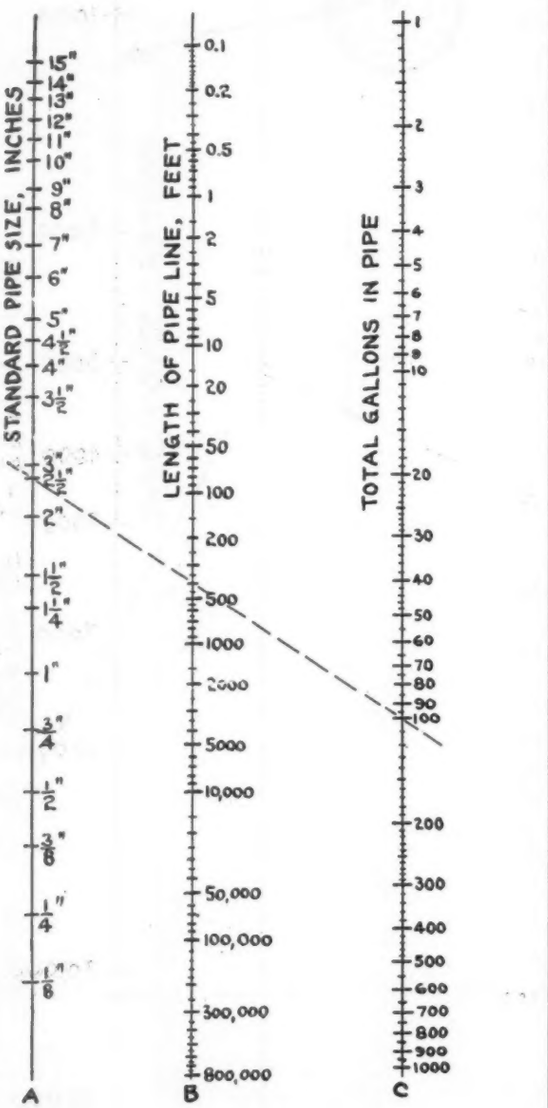
Thus the dotted line drawn across this chart shows that if the pipe size is 2½ inches (column A) and the length of line is 400 feet (column B) the volume of the pipe (column C), is 100 gallons.

For a length of pipe which is found to hold more than 1,000 gals. the volume is readily found for 1/10th or 1/100th of the length and the C scale reading multiplied accordingly.

Or, if it is desired to know the length of pipe line required to hold a given number of gallons, or the size of the pipe necessary to hold a given number of gallons within certain limitations of length, the chart may be conveniently applied. In other words, knowing two factors in any two of the three columns, the unknown in the third column is quickly found.

Here is another "trick": To determine the volume of a ½-inch pipe one foot long, the easiest way is to run a line through the ½-inch, column A, and the 10,000 in column B. The intersection with column C says 160 gallons, but that, of course, is for a pipe line 10,000 ft. long. By merely pointing off four places to the left we have 0.016 gal, as the volume of a ½-inch pipe one foot long.

* Contributed by W. F. Schaphorst (M.E.), Newark, N. J.



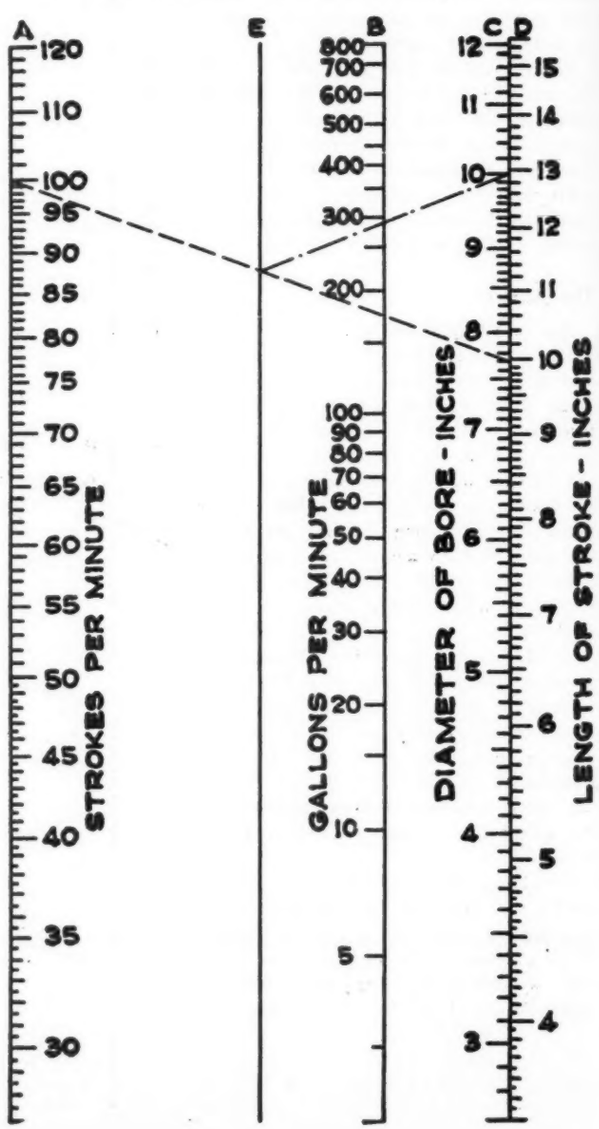
CAPACITY OF RECIPROCATING PUMPS

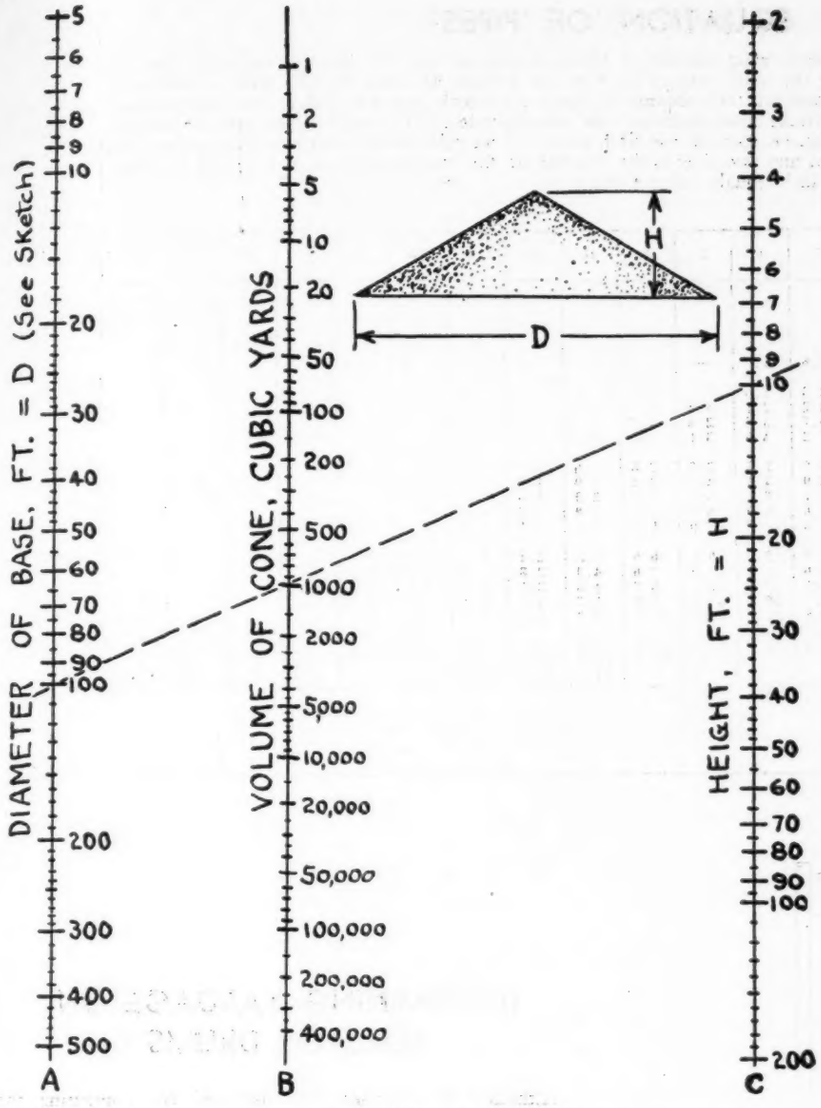
This nomograph shows the capacity of a reciprocating pump operating without slip where the size and number of strokes is known.

Example:

A pump of 10-in. bore, 10-in. stroke running 100 strokes per minute: Locating 100 on line "A" and 10-in. on line "D" we draw a line between them; then locating the intersection of this line with line "E" and locating 10-in. on line "C" we draw a connecting line. Where this line crosses "B" we have the delivery, or 290 G.P.M., of the reciprocating pump.

(From "Data Handbook" of Economy Pumps, Inc.)





CONTENTS OF CONICAL PILES*

Frequently it becomes desirable or necessary to estimate yardage in a pile of dirt, sand, stone, gravel, coal, etc.

Without any figuring whatever the accompanying chart quickly gives the number of cubic yards in any conical pile.

For example, how many cubic yards in a conical pile whose based diameter is 100 ft. and whose height is 10 ft.?

The dotted line drawn across the chart shows how it is done. Run the line through the 100 ft. diameter, column A, and the 10 ft. height, Column C, and the intersection with column B gives the answer as a little less than 1000 cubic yards.

The range of the chart takes care of all diameters from 5 to 500 ft. and all heights from 2 to 200 ft. However, in the event that diameters or heights should be greater or less the same chart is still applicable. Thus if the diameter should be 1000 ft. instead of 100 ft. and if the height should be 100 ft. instead of 10 ft., the same dotted line would solve the problem excepting that the answer would be 1,000,000 cubic yards instead of 1000 cubic yards. In that case the rule is this: For every cipher added to column A, add two ciphers to the answer in column B, and for every cipher added to column C, add one cipher to the answer in column B. This means that when the problem is 1000 ft. diameter and 100 ft. height, three ciphers must be added to the result in column B.

*Contributed by W. F. Schaphorst, M.E.

LAND MEASURE

A Quarter Section of 160 Acres Divided to Show Relationship of Rods, Chains and Feet

A rod is 16½ feet.

A chain is 66 feet or 4 rods.

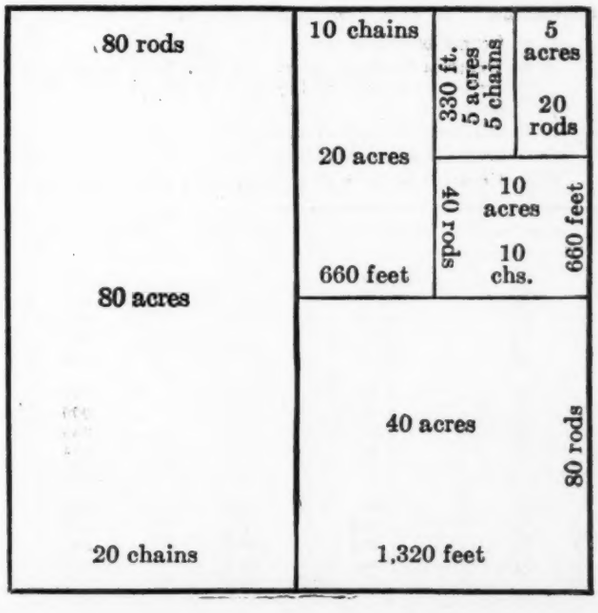
A mile is 320 rods, 80 chains or 5,280 ft.

A square rod is 272¼ square feet.

An acre contains 43,560 square feet.

An acre contains 160 square rods.

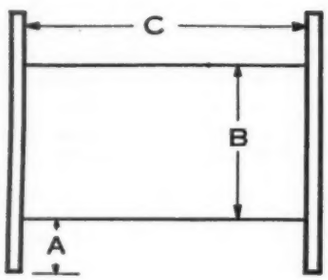
An acre is about 208¾ feet square.



EQUATION OF PIPES

It is frequently desired to know what number of pipes of a given size are equal in carrying capacity to one pipe of a larger size. At the same velocity of flow the volume delivered by two pipes of different sizes is proportional to the squares of their diameters; thus one 4-inch pipe will deliver the same volume as four 2-inch pipes. With the same head, however, the velocity is less in the smaller pipe, and the volume delivered varies about as the square root of the fifth power. This table is calculated on this basis. The figures opposite the intersection of any two sizes is the number of the smaller-sized pipes required to equal one of the larger; thus one 4-inch equals 5.7 two-inch.

Dia. in.	1	2	3	4	5	6	7	8	10	12	14	16	18	20	24	30	36
2	5.7	1.															
3	15.6	2.8	1.														
4	32.	5.7	2.1	1.													
5	55.9	9.9	3.6	1.7	1.												
6	88.2	15.6	5.7	2.8	1.6	1.											
7	130.	22.9	8.3	4.1	2.3	1.5	1.										
8	181.	32.	11.7	5.7	3.2	2.1	1.4	1.									
10	316.	55.9	20.3	9.9	5.7	3.6	2.4	1.7	1.								
11	401.	70.9	25.	12.5	7.2	4.6	3.1	2.2	1.3								
12	499.	88.2	32.	15.6	8.9	5.7	3.8	2.8	1.6	1.							
13	609.	108.	39.1	19.	10.9	7.1	4.7	3.4	1.9	1.2							
14	733.	130.	47.	22.9	13.1	8.3	5.7	4.1	2.3	1.5	1.						
15	787.	154.	55.9	27.2	15.6	9.9	6.7	4.8	2.8	1.7	1.2						
16		181.	65.7	32.	18.3	11.7	7.9	5.7	3.2	2.1	1.4	1.					
17		211.	76.4	37.2	21.3	13.5	9.2	6.6	3.8	2.4	1.6	1.2					
18		243.	88.2	43.	24.6	15.6	10.6	7.6	4.3	2.8	1.9	1.3	1.				
19		278.	101.	49.1	28.1	17.8	12.1	8.7	4.8	3.2	2.1	1.5	1.1				
20		316.	115.	55.9	32.	20.3	13.8	9.9	5.7	3.6	2.4	1.7	1.3	1.			
22		401.	146.	70.9	40.6	25.7	17.5	12.5	7.2	4.6	3.1	2.2	1.7	1.3			
24		499.	181.	88.2	50.5	32.	21.8	15.6	8.9	5.7	3.8	2.8	2.1	1.6	1.		
30								27.2	15.6	10.0	6.7	4.8	3.6	2.8	1.75	1.0	
36									24.6	15.6	10.6	7.6	5.7	4.3	2.76	1.6	1.0



FORMULA:— $L = (A + B) \times A \times C \times K$

L = Length of rope in feet.

A = Depth of flange in inches. In computing capacity of reels "A" is reduced 1½" to 2" to provide for a clearance.

B = Diameter of drum in inches.

C = Width of drum in inches.

K = Constant which is given below for a given size of rope.

Rope Dia.	Value of "K"	Rope Dia.	Value of "K"
1/32	266.24	7/8	.342
1/16	66.56	1	.262
3/32	29.76	1 1/8	.207
1/8	16.64	1 1/4	.167
5/32	10.76	1 3/8	.138
3/16	7.44	1 1/2	.116
1/4	4.16	1 5/8	.099
5/16	2.67	1 3/4	.085
3/8	1.86	1 7/8	.074
7/16	1.37	2	.066
1/2	1.05	2 1/8	.058
9/16	.828	2 1/4	.052
5/8	.672	2 3/8	.046
3/4	.465	2 1/2	.042

DETERMINING YARDAGE ON REELS OR DRUMS

Although the formula was designed for computing the length of cable, etc., of various diameters, which a reel or drum of given dimensions will accommodate, the method is equally valuable for determining footage remaining on a reel or drum, for inventory purposes or other reasons. In such instances the depth (A) is the depth (in inches) of rope, cable, wire, etc., remaining on the drum or reel.

Example: Assume a reel having a 5 in. core (B) and a width of 10 in. (C). The material is ¼ in. in diameter and its depth on the core is 2 in. (A).

$$(B + A) \times A \times C = X$$
$$(5 + 2) \times 2 \times 10 = 140$$

Now refer to table of factors for the "K" value for ¼ in. materials, such being 4.16 ∴ The footage is $140 \times 4.16 = 582$ ft. or, if ½ in. material $140 \times 1.05 = 147$ ft.

If it is desired to determine the length of rope, wire, rubber hose, copper tubing, packing, caulking yarn, etc., wound on a drum or reel, the accompanying formula will prove very helpful.

The sketch, with formula and factors, appeared in Wire Rope Cat. No. 20 of the Hazard Wire Rope Div. of American Chain and Cable Co. Inc.

WEIGHTS AND MEASURES

Troy Weight

3.086 grains = 1 carat
24 grains = 1 dwt.
20 dwts. = 1 ounce
12 ounces = 1 pound
Used for weighing gold, silver, and jewels.

Apothecaries' Weight

20 grains = 1 scruple
3 scruples = 1 dram
8 drams = 1 ounce
12 ounces = 1 pound
The ounce and pound in this weight are the same as in Troy Weight.

Avoirdupois Weight

1 grain (Troy) = 1 grain (Apoth.) = 1 grain (Avdp.)
27 11/32 grams = 1 dram
16 drams = 1 ounce = 437.5 grains
16 ounces = 1 pound
25 pounds = 1 quarter
4 quarters = 1 cwt.
2,000 lbs. = 1 short ton
2,240 lbs. = 1 long ton
1 long ton = 1 British ton

Dry Measure

2 pints = 1 quart
1 quart = 67.2 cu. in.
8 quarts = 1 peck
4 pecks = 1 bushel
1 British bushel = 1.032 U. S. bushel

Liquid Measure

4 gills = 1 pint
16 fluid ounces = 1 pint
2 pints = 1 quart
4 quarts = 1 gallon
1 gallon = 231 cu. in.
31½ gallons = 1 barrel
2 barrels = 1 hogshead
1 British Imperial gallon = 1.200 U. S. gallons
1 cubic foot of water contains 7.48 gallons and weighs 62.321 lb.

Linear Measure

1 mil = 0.001 inch
12 inches = 1 foot
3 feet = 1 yard
5½ yards = 1 rod
40 rods = 1 furlong
8 furlongs = 1 statute mile
5280 feet = 1 statute mile
3 miles = 1 league

Square Measure

1 circular mil = 0.7854 square mils
1,000,000 square mils = 1 square inch
144 square inches = 1 sq. ft.
9 sq. ft. = 1 sq. yard
4 roods = 1 acre = 43560 sq. ft.
30¼ sq. yds. = 1 sq. rod
40 sq. rods = 1 rood
640 acres = 1 sq. mile

Surveyor's Measure

7.92 inches = 1 link
25 links = 1 rod
4 rods = 1 chain
10 sq. chains or 160 sq. rods = 1 acre
36 sq. miles (6 miles square) = 1 township
43560 sq. ft. = 1 acre
640 acres = 1 sq. mile

Mariners' Measure

6.08 feet = 1 fathom
120 fathoms = 1 cable length
8.31 cable lengths = 1 nautical mile
6080 feet = 1 nautical mile
1 nautical mile = 1.15 statute mile
1 knot is a speed of 1 nautical mile per hour

Paper Measure

24 sheets = 1 quire
20 quires = 1 ream
2 reams = 1 bundle
5 bundles = 1 bale

Cubic Measure

1 cu. cm. = .061 cu. in.
27 cu. ft. = 1 cu. yd.
40 cu. ft. = 1 ton (shipping)
231 cu. in. = 1 standard gallon
2150.42 cu. in. = 1 standard bushel
1 cu. ft. = 4/5 of a bushel
1728 cu. in. = 1 cu. ft.
128 cu. ft. = 1 cord (wood)

Household Measure

60 drops = 1 teaspoon
2 teaspoons = 1 dessert spoon
3 teaspoons = 1 tablespoon
16 tablespoons = 1 cup
2 gills = 1 cup
2 cups = 1 pint

METRIC EQUIVALENTS

Linear Measure

1 millimeter = 0.03937 inches
1 centimeter = 0.3937 inches
1 decimeter = 3.937 in. = 0.328 ft.
1 meter = 39.37 in. = 1.0936 yards
1 dekameter = 1.9884 rods
1 kilometer = 0.62137 mile
1 inch = 2.54 centimeters
1 foot = 3.048 decimeters
1 rod = 0.5029 dekameter
1 yard = 0.9144 meter
1 mile = 1.6093 kilometers

Square Measure

1 sq. cm. = 0.1550 sq. in.
1 sq. decimeter = 0.1076 sq. ft.
1 sq. meter = 1.196 sq. yds.
1 hectare = 2.47 acres
1 sq. kilometer = 0.386 sq. miles
1 sq. in. = 6.452 sq. cm.
1 sq. foot = 9.2903 sq. decimeters
1 sq. yard = 0.8361 sq. meter
1 sq. mile = 2.59 sq. kilometers

Weights

1 dyne = .00102 grains
1 gram = 0.03527 ounces
1 kilogram = 2.2046 lbs.
1 metric ton = 2205 lbs.
1 pound = 0.4536 kilograms
1 metric ton = 1.1023 short tons
1 ounce = 28.35 grams = 437.5 grains

WEIGHTS OF MATERIALS

Pounds per Cubic Foot — Average

BRICK	
Common Red	100
Silica	105
CEMENT	
Portland	94
Hydraulic	60
COAL AND COKE	
Anthracite	53 to 57
Bituminous	49
Charcoal	18
Coke	26
CONCRETE	
Cement, fine	137
Rubble, coarse	119
EARTH	
Loam, dry, loose	76
Loam, packed	95
Loam, soft, loose mud	108
Loam, dense mud	125
LIME	
Quick, loose lumps	53
Quick, fine	73
LIME STONE	
Large blocks	168
Irregular lumps	96
MASONRY	
Granite or limestone	165
Mortar, rubble	154
Dry	138
Sandstone, dressed	144
METALS	
Aluminum	166
Brass, cast	524
Bronze	534
Copper, cast	537
Copper, rolled or wire	555
Iron, cast	450
Iron, wrought	482
Lead, cast	708
Lead, rolled	711
Steel, cast	490
Steel, rolled	495
Tin, cast	459
Zinc, cast	438
OILS	
Engine	55
Crude	48
Petroleum	55
Gasoline	43
SAND	
Dry and loose	100
Dry and packed	110
Wet and packed	130
Gravel, packed	118
Gravel, bank	111
Gravel, dry	74
WATER	
Water, as ice	59
Water, at 32° F.	62
Water, at 212° F.	60

ROOTS AND POWERS OF NUMBERS*

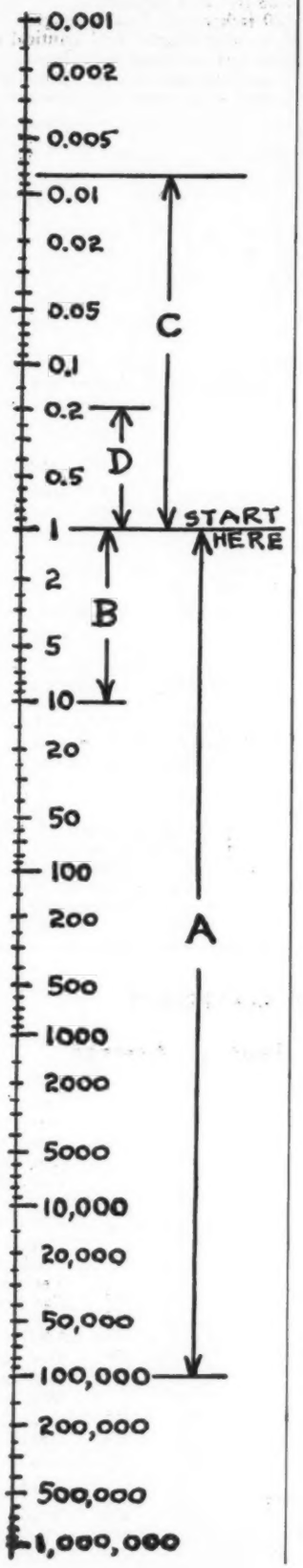
A Chart Which Saves Many Tables

Take any slide rule and lay it end to end nine times, and each time lay off the principal dividing lines, you will have a chart exactly like this one except that it will be much longer and therefore it will be much more accurate. That is what I did in preparing this chart. Then I reduced it to this much smaller size. To keep track of the digits you simply read the numbers exactly as they stand on the chart. No juggling of figures is necessary. I do not know of any other other method that is as simple as this. All other methods require "juggling of digits," as they say.

For example, what is the 5th root of 100,000? Measure the distance A from 1 to 100,000 as indicated on the chart. The distance B must then be exactly 1/5th of the distance A and there is your answer, namely, 10. In other words, divide the distance A by the root and the quotient shows you the distance to measure from 1 to find the answer. Always measure from "1" in either direction. "One" is always the starting point. To extract the square, cube, or other root of fractions is usually more complex than extracting roots of whole numbers. However, with this chart one is just as easy as the other.

For example, what is the cube root of .008? Measure the distance C from .008 to the starting point "1" and divide it by 3 and you get the distance D which tells us that the answer is 0.2.

A method that is as easy as any to find a third, fourth, fifth, etc., of any distance, is to use a pair of dividers. Adjust the dividers until you get the distance D exactly ⅓ of the distance C and the chart gives the answer without any mathematical calculations whatever. With this chart you can determine the 3.127 power for instance—any power in fact. And you can extract the 4.37 root or any other root, all without mathematical jugglery.



*From an article by W. E. Schaphorst, M. E., Newark, N. J., in WATER WORKS & SEWERAGE, January, 1939.

Inclined Diagonal Pipe Runs Calculating Pipe Lengths

By CHARLES FRICK

Water works men may find the following formulas interesting and helpful in figuring lengths of pipe and tie rods on inclined diagonal runs.

The formulas are also useful in finding the approximate angle of fitting, theta (Θ), required (when bell and spigot pipe and fittings are used) when the dimensions in three planes have been decided upon.

The evolution of the formulas (see illustration) are also given in case the principle of revolution to a vertical plane may have further advantages in similar problems.

The subtraction of the center to end of spigot and center to back of bell taken from D gives the true length of pipe required.

Sketch Explanatory of Formulas for Lengths of Pipe for Diagonal Runs and Angle of Fittings

A.—When measurements in three planes are known, then

$$D = \sqrt{A^2 + B^2 + C^2} \qquad \text{Formula I}$$

$$L\ (\theta)^{-\tan} = \frac{\sqrt{A^2 + B^2}}{C} \qquad \text{Formula II}$$

Example: Let A = 5′6″, B = 3′0″, C = 14′9″
Find (Θ) and length of pipe required on 8″ line.

$$D = \sqrt{(5.5)^2 + (3)^2 + (14.75)^2}$$
$$= \sqrt{30.25 + 9 + 217.56} = 16.025' \text{ say } 16'0''$$

$$L\ (\theta)^{-\tan} = \frac{\sqrt{(5.5)^2 + (3)^2}}{14.75} = \frac{\sqrt{30.25 + 9}}{14.75}$$

$$= \frac{\sqrt{39.25}}{14.75} = \frac{6.265}{14.75} = 0.42474$$

L (Θ) = 23° + and a one-sixteenth curve may be used.
Length of pipe = D — (C to E of S. + C to B of B.)
= 16′0″ — (2′1″+) = 13′11″—

B.—When measurements in two planes are known and angle of fitting (Θ) decided upon, then

$$D = \sqrt{A^2 + B^2} \times \text{Csc } (\theta) \qquad \text{Formula III}$$

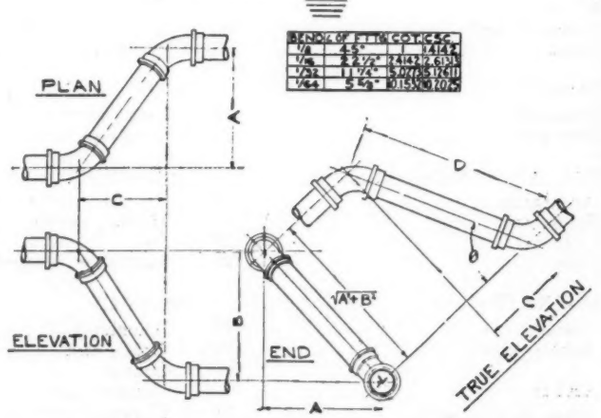
$$C = \sqrt{A^2 + B^2} \times \text{Cot } (\theta) \qquad \text{Formula IV}$$

Example: Let A = 8′0″, B = 9′6″, (Θ) = 45°
Find—C and length of pipe required on 12″ line.

$$D = \sqrt{(8)^2 + (9.5)^2} \times \text{Csc } 45°$$
$$= \sqrt{64 + 90.25} \times 1.4142$$
$$= 17.56' = 17'6\tfrac{3}{4}''$$

Length of pipe = D — (C to E of S. + C to B of B.)
= 17′6¾″ — (2′1⅞″) = 15′4⅞″

$$C = \sqrt{(8)^2 + (9.5)^2} \times \text{Cot } 45°$$
$$= \sqrt{64 = 90.25} \times 1$$
$$= 12.42 \times 1 = 12.42' = 12'5''$$



Sketch Explanatory of Formulas for Lengths of Pipe for Diagonal Runs and Angle of Fittings

AREAS OF CIRCLES—SQUARES—SQUARE ROOTS

(Also Fractions to Decimal Equivalent.)

No. N Fraction	Decimal	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
1/16	.0625	.0039	.2500	.0031
1/8	.125	.0156	.3536	.0125
3/16	.1875	.0352	.4330	.0276
1/4	.25	.0625	.5000	.0491
5/16	.3125	.0977	.5590	.0767
3/8	.375	.1406	.6124	.1105
7/16	.4375	.1914	.6614	.1503
1/2	.50	.2500	.7071	.1964
9/16	.5625	.3164	.7500	.2485
5/8	.625	.3906	.7906	.3068
11/16	.6875	.4727	.8297	.3712
3/4	.75	.5625	.8660	.4418
13/16	.8125	.6602	.9014	.5185
7/8	.875	.7656	.9354	.6013
15/16	.9375	.8789	.9683	.6903
1	1.	1.000	1.000	.7854
1 1/8	1.125	1.266	1.061	.9940
1 1/4	1.25	1.563	1.118	1.227
1 3/8	1.375	1.891	1.175	1.485
1 1/2	1.50	2.250	1.225	1.767
1 5/8	1.625	2.641	1.275	2.074
1 3/4	1.75	3.063	1.323	2.405
1 7/8	1.875	3.516	1.369	2.761
2	2.	4.000	1.414	3.142
2 1/8	2.125	4.516	1.458	3.547
2 1/4	2.25	5.063	1.500	3.976
2 3/8	2.375	5.641	1.541	4.430
2 1/2	2.50	6.250	1.581	4.909
2 5/8	2.625	6.891	1.620	5.412
2 3/4	2.75	7.563	1.658	5.940
2 7/8	2.875	8.266	1.696	6.492
3	3.	9.000	1.732	7.069
3 1/8	3.125	9.766	1.768	7.670
3 1/4	3.25	10.56	1.803	8.296
3 3/8	3.375	11.39	1.837	8.946
3 1/2	3.50	12.25	1.871	9.621
3 5/8	3.625	13.14	1.904	10.32
3 3/4	3.75	14.06	1.937	11.04
3 7/8	3.875	15.02	1.969	11.79
4	4.	16.00	2.000	12.57
4 1/8	4.125	17.02	2.031	13.36
4 1/4	4.25	18.06	2.062	14.19
4 3/8	4.375	19.14	2.092	15.03
4 1/2	4.50	20.25	2.121	15.90
4 5/8	4.625	21.39	2.151	16.80
4 3/4	4.73	22.56	2.180	17.72
4 7/8	4.875	23.77	2.208	18.67
5	5.00	25.00	2.236	19.64
5 1/4	5.25	27.56	2.291	21.65
5 1/2	5.50	30.25	2.345	23.76
5 3/4	5.75	33.06	2.398	25.97
6	6.	36.00	2.450	28.27
6 1/4	6.25	39.06	2.500	30.68
6 1/2	6.50	42.25	2.550	33.18
6 3/4	6.75	45.56	2.598	35.78
7	7.	49.00	2.646	38.48
7 1/4	7.25	52.56	2.693	41.28
7 1/2	7.50	56.25	2.739	44.18
7 3/4	7.75	60.06	2.784	47.17
8	8.00	64.00	2.828	50.27
8 1/4	8.25	68.06	2.872	53.46
8 1/2	8.50	72.25	2.916	56.75
8 3/4	8.75	76.56	2.958	60.13
9	9.00	81.00	3.000	63.62
9 1/4	9.25	85.56	3.041	67.20
9 1/2	9.50	90.25	3.082	70.88
9 3/4	9.75	95.06	3.123	74.66

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
10	100	3.162	78.54
11	121	3.317	95.03
12	144	3.464	113.1
13	169	3.606	132.7
14	196	3.742	153.9
15	225	3.873	176.7
16	256	4.000	201.1
17	289	4.123	227.0
18	324	4.243	254.5
19	361	4.359	283.5
20	400	4.472	314.2
21	441	4.583	346.4
22	484	4.690	380.1
23	529	4.796	415.5
24	576	4.899	452.4
25	625	5.000	490.9
26	676	5.099	530.9
27	729	5.196	572.6
28	784	5.292	615.8
29	841	5.385	660.5
30	900	5.477	706.9
31	961	5.568	754.8
32	1024	5.657	804.2
33	1089	5.745	855.3
34	1156	5.831	907.9
35	1225	5.916	962.1
36	1296	6.000	1017.9
37	1369	6.083	1075.2
38	1444	6.164	1134.1
39	1521	6.245	1194.6
40	1600	6.325	1256.7
41	1681	6.403	1320.3
42	1764	6.481	1385.4
43	1849	6.557	1452.2
44	1936	6.633	1520.5
45	2025	6.708	1590.4
46	2116	6.782	1661.9
47	2209	6.856	1734.9
48	2304	6.928	1809.6
49	2401	7.000	1885.7
50	2500	7.071	1936.5
51	2601	7.141	2042.8
52	2704	7.211	2123.7
53	2809	7.280	2206.2
54	2916	7.349	2290.2
55	3025	7.416	2375.8
56	3136	7.483	2463.0
57	3249	7.500	2551.8
58	3364	7.616	2642.1
59	3481	7.681	2734.0
60	3600	7.746	2827.4
61	3721	7.810	2922.5
62	3844	7.874	3019.1
63	3969	7.937	3117.2
64	4096	8.000	3217.0
65	4225	8.062	3318.3
66	4356	8.124	3421.2
67	4489	8.185	3525.7
68	4624	8.246	3631.7
69	4761	8.307	3739.3
70	4900	8.367	3848.5
71	5041	8.426	3959.2
72	5184	8.485	4071.5
73	5329	8.544	4185.4
74	5476	8.602	4300.8
75	5625	8.660	4417.9

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
76	5776	8.718	4536.5
77	5929	8.775	4656.6
78	6084	8.832	4778.4
79	6241	8.888	4901.7
80	6400	8.944	5026.5
81	6561	9.000	5153.0
82	6724	9.055	5281.0
83	6889	9.110	5410.6
84	7056	9.165	5541.8
85	7225	9.220	5674.5
86	7396	9.274	5808.8
87	7569	9.327	5944.7
88	7744	9.381	6082.1
89	7921	9.434	6221.1
90	8100	9.487	6361.7
91	8281	9.539	6503.9
92	8464	9.592	6647.6
93	8649	9.644	6792.9
94	8836	9.695	6939.8
95	9025	9.747	7088.2
96	9216	9.798	7238.2
97	9409	9.849	7389.8
98	9604	9.900	7543.0
99	9801	9.950	7697.7
100	10000	10.00	7854.0
101	10201	10.05	8011.9
102	10404	10.10	8171.3
103	10609	10.15	8332.3
104	10816	10.20	8494.9
105	11025	10.25	8659.0
106	11236	10.30	8824.7
107	11449	10.34	8992.0
108	11664	10.39	9160.9
109	11881	10.44	9331.3
110	12100	10.49	9503.3
111	12321	10.54	9676.9
112	12544	10.58	9852.0
113	12769	10.63	10029
114	12996	10.68	10207
115	13225	10.72	10387
116	13456	10.77	10568
117	13689	10.82	10751
118	13924	10.86	10936
119	14161	10.91	11122
120	14400	10.95	11310
121	14641	11.00	11499
122	14884	11.05	11690
123	15129	11.09	11882
124	15376	11.14	12076
125	15625	11.18	12272
126	15876	11.23	12469
127	16129	11.27	12668
128	16384	11.31	12868
129	16641	11.36	13070
130	16900	11.40	13273
131	17161	11.45	13478
132	17424	11.49	13685
133	17689	11.53	13893
134	17956	11.58	14103
135	18225	11.62	14314
136	18496	11.66	14527
137	18769	11.70	14741
138	19044	11.75	14957
139	19321	11.79	15175
140	19600	11.83	15394
141	19881	11.87	15615

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
142	20164	11.92	15837
143	20449	11.96	16061
144	20736	12.00	16286
145	21025	12.04	16583
146	21316	12.08	16742
147	21609	12.12	16972
148	21904	12.17	17203
149	22201	12.22	17437
150	22500	12.25	17671
151	22801	12.29	17908
152	23104	12.33	18146
153	23409	12.37	18385
154	23716	12.41	18627
155	24025	12.45	18869
156	24336	12.49	19113
157	24649	12.53	19359
158	24964	12.57	19607
159	25281	12.61	19856
160	25600	12.65	20106
161	25921	12.69	20358
162	26244	12.73	20613
163	26569	12.77	20867
164	26896	12.81	21124
165	27225	12.85	21382
166	27556	12.88	21642
167	27889	12.92	21904
168	28224	12.96	22168
169	28561	13.00	22432
170	28900	13.04	22698
171	29241	13.08	22966
172	29584	13.11	23235
173	29929	13.15	23506
174	30276	13.19	23779
175	30625	13.23	24053
176	30976	13.27	24328
177	31329	13.30	24606
178	31684	13.34	24885
179	32041	13.38	25165
180	32400	13.42	25447
181	32761	13.45	25730
182	33124	13.49	26016
183	33489	13.53	26302
184	33856	13.56	26590
185	34225	13.60	26880
186	34596	13.64	27172
187	34969	13.67	27465
188	35344	13.71	27759
189	35721	13.75	28055
190	36100	13.78	28353
191	36481	13.82	28652
192	36864	13.86	28953
193	37249	13.89	29255
194	37636	13.93	29559
195	38025	13.96	29865
196	38416	14.00	30172
197	38809	14.04	30481
198	39204	14.07	30791
199	39601	14.11	31103
200	40000	14.14	31416
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...	.....	....	.....
...	.....	....	.....
...	.....	....	.....
...	.....	....	.....
...	.....	....	.....

Index TO ADVERTISERS

A

Albright & Friel, Inc. 134
Alvord, Burdick & Howson 134
Aluminum Company of America 6
American Brass Company, The 276D
American Cast Iron Pipe Co. 120
American Norit Company, Inc. 8
American Smelting and Refining Co. 276B
American Well Works, The 12
Anderson Valve Corp. ..... Data Section 57
Anthracite Equipment Corp. ..... 135, Data Section 149
A. S. G. Pipe Lining Co. 136
Atlas Mineral Products Co. of Pa., The ..... 135, Data Section 107

B

Badger Meter Manufacturing Co. 9
Bailey Meter Co. ..... 131, Data Section 33
Barrett Haentjens & Co. ..... Data Section 50
Black & Veatch 134
Blake, Frank N. 135
Brainard & Co., F. S. 135
Buck, Seifert and Jost 134
Builders-Providence, Inc. ..... 21, Data Section 34-35
Burns & McDonald Engr. Co. 134

C

Calgon, Inc. ..... 32, Data Section 132
Carborundum Company, The 34
Carter Company, Ralph B. ..... Data Section 191
Cast Iron Pipe Research Assn., The 268C
Cement Lined Pipe Co. 130
Central Foundry Company 119
Chain Belt Company 116
Champion Corporation 115
Chapman Valve Manufacturing Co. ..... Second Cover
Chester Engineers, The 134
Chicago Bridge & Iron Company ..... Data Section 82-83
Chicago Pump Company ..... 268A, Data Section 232
Cole Manufacturing Co., R. D. ..... Data Section 87
Connelly Iron Sponge & Governor Co. 136

D

Darco Corporation 123
DeLaval Steam Turbine Co. 36
Diamond Alkali Company 15
Dorr Company, Inc., The ..... Third Cover
Dow Chemical Company, The ..... Data Section 243
Dracco Corporation 118

E

Economy Pumps, Inc. 113
Edson Corporation, The 133
Electro Rust-Proofing Co. 120

F

Ferguson, S. F. 122
Flexible Sewer Rod Equipment Co. ..... 114, Data Section 76
Flexible Underground Pipe-Cleaning Co. ..... Data Section 76
Ford Meter Box Co. 126
Fulton, Edward A. 134

G

Gardner-Denver Co. 16
General Paint Corporation. ..... Data Section 66
Glace, I. M. 134
Golden-Anderson Valve Spec. Co. ..... 128, Data Section 91
Graver Tank and Mfg. Co. ..... 33, Data Section 155
Greeley & Hansen 134

H

Havens and Emerson 134
Hellige, Inc. ..... Data Section 150
Hill, Hubbell & Co. ..... Data Section 66
Homelite Corporation, The 121
Hydraulic Development Corp. ..... 132, Data Section 103

I

Industrial Chemical Sales ..... 268D, Data Section Facing Page 1
Innis, Speiden & Co. ..... Data Section 244
Infilco, Incorporated ..... 24, Data Section 140-141
Iowa Valve Co. 132

J

Jeffrey Manufacturing Company ..... Data Section 182-183
Johns-Manville ..... 10-11-39-117, Data Section 70-71-72-73

K

Knowles, Inc., Morris 134

L

Lakeside Engineering Corporation ..... 114, Data Section 205
Lancaster Research Laboratories 134
Layne & Bowler, Inc. 126
Leadite Company, The 268B
Leitz, Inc., E. 125
Link-Belt Company 30
Lock Joint Pipe Company 14
Ludlow Valve Mfg. Co., Inc., The 20

M

M & H Valve and Fittings Company ..... 130, Data Section 111
Mabbs Hydraulic Packing Co. 133
Mathews Hydrants 25
Mathieson Alkali Works, Inc., The 23
Metcalf & Eddy 134
Mueller Brass Co. ..... 22, Data Section 131
Municipal Service Co. 128

N

National Lime Association 120
National Machine Works 7
National Technical Laboratories 276A
National Water Main Cleaning Co. ..... 127, Data Section 75
Neptune Meter Co. 42
Newsom & Aldrich 134
Niagara Alkali Company 252AB
Nichols Engineering & Research Corp. ..... 122, Data Section 249
Northrup & Company, Inc. ..... Data Section 108
Nussbaumer & Clarke, Inc. 134

O

Omega Machine Company ..... 115, Data Section 161

P

Pacific Flush Tank Company ..... Data Section 216
Peerless Pump Division 31
Pennsylvania Salt Mfg. Company ..... 276C, Data Section 166-167
Permutit Company, The ..... Data Section 151
Philadelphia Quartz Co. 135
Phipps & Bird, Inc. 131
Phoenix Meter Corp. 17
Pirnie, Malcolm 134
Pitometer Company, The 37-134
Pittsburgh-Des Moines Steel Co. ..... 132, Data Section 84
Pittsburgh Equitable Meter Co. 4-5-244AB
Pomona Pump Co. ..... Data Section 48-49
Proportioneers, Inc. ..... 40, Data Section 156—Facing Page 169

R

Raisch and Associates, William 134
Ranney Water Collector Corp. 19
Reilly Tar & Chemical Corp. 124
Rensselaer Valve Co. 29
Riddick, Thomas M. 135
Roberts Filter Mfg. Co. 3
Roots Connersville Blower Corp. 129
Ross Valve Mfg. Co., Inc. ..... Data Section 88
Royer Foundry & Machine Co. ..... Data Section 239
Runyon & Carey 135
Russell & Axon 135

S

Salomon & Bro., L. A. 8
Schramm, Inc. ..... Data Section 81
Simplex Valve & Meter Co. ..... 13, Data Section 42-43
Sirrine & Company, J. E. 135
Smith Company, S. Morgan 18
Smith Mfg. Co., The A. P. 35
Solvay Sales Corporation 119
Sparling, R. W. ..... 133, Data Section 45
Standard Dry Wall Products, Inc. 132
Standard Silicate Division 15
Stanley Engineering Company 135
Stewart, W. H. ..... 130, Data Section 175
Streamline Pipe & Fittings Division ..... 22, Data Section 131
Stuart-Brumley Corp. ..... 113, Data Section 142

T

Tate Pipe Linings, Inc. 129
Taylor and Co., W. A. 119
Tennessee Corporation ..... 130, Data Section 196
Thomson Meter Company 42
Treasury Department 38

U

Underpinning & Foundation Co., Inc. 253
U. S. Pipe & Foundry Co. ..... 260AB, Data Section 102

V

Vapor Recovery Systems Co. ..... 128, Data Section 227
Virginia Smelting Co. 130
Vogt Manufacturing Co. 133

W

Wallace & Tiernan Co., Inc. ..... Back Cover, Data Section 168-215
Warren Foundry & Pipe Corp. 133
Water Leak Detector Co. 135
Weston, L. A. 132
Weston and Sampson 135
Whitman and Howard 135
Whitman, Requardt & Smith 135
Wilson Chemical Feeders, Inc. ..... Data Section 162
Wood Company, R. D. 25
Worthington-Gamon Meter Company 117
Worthington Pump and Machinery Corp. 28
Wyckoff & Son Company, A. 127

Z

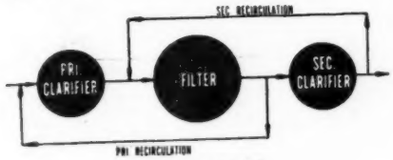
Zeolite Chemical Co. 26-27

280 PAGES IN DATA SECTION—TOTAL PAGES THIS ISSUE—422

INDEX TO REFERENCE AND DATA READING PAGES CAN BE FOUND AT BEGINNING OF DATA SECTION

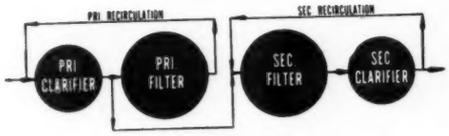
SOME BIOFILTRATION FACTS

Some Preferred Biofiltration Flowsheets



SINGLE STAGE

TWO STAGE A



TWO STAGE B

Some Typical Operating Data

	Single Stage	Two Stage—A	Two Stage—B
Flow—Percent Design	62	100	64
Overflow Rates—Gals/Sq. ft./Day			
Primary Clarifier	460	730	655
Secondary Clarifier	440	920	760
Recirculations			
Primary Ratio	1.00	1.26	2.31
Secondary Ratio	0.93	0 44	2.86
Suspended Solids			
Raw—P.P.M.	217	221	279
Final—P.P.M.	9	24	19
Removal—Percent	95.9*	89.1	93.2
B.O.D.'s			
Raw—P.P.M.	258	209	327
Final—P.P.M.	9	27	31
Removal—Percent	96.5*	87	90.5
Duration Tests	3 mos.	8 mos.	2½ weeks

*Single stage removals high compared with two stage account of relatively lower clarifier overflow rates.

★ **First, the Defense, now the War Effort have brought broad recognition to the Biofiltration System, an improved method of trickling filter treatment announced late in 1939.**

More than 100 units are in use or under construction in 33 of the 48 states. Most of these are on the War Front, at army camps, naval bases, airfields and ordnance plants. Design populations range from 200 to 65,000.

The three flowsheets on this page have emerged as the best from among the dozen or more investigated or tested. Almost half the installations to date are of these three types.

● **Write for a copy of our bulletin on "The Biofiltration System"—24 page illustrated booklet containing photos, layouts, cost and operating data and practical design information.**

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The Biofiltration System comprises one or more combinations of Clarifiers and Filters wherein the unthickened filter discharge is recycled back to the Clarifiers. Single or two stage systems may be employed to give results comparable with (1) Standard Trickling Filters (2) Chemical Precipitation or (3) Activated Sludge. ∿ ∿ The Biofiltration System (a) gives a uniform effluent with fluctuating feeds (b) permits filter loadings up to 10 times normal with 3 foot media depths and (c) costs 25-50 percent less to operate than Standard Trickling Filters or the Activated Sludge Process.

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ON GUARD ON THE GO

W&T Chlorination Trailer sterilizes a water main extension at Waterbury, Conn.

A dependable gasoline motor provides power for solution feed against main pressures as high as 125 lb. per sq. in.

The unit is quickly moved to the scene of action by a passenger car or commercial vehicle.

W&T *Chlorination* TRAILER

The W&T Chlorination Trailer is specifically fitted to cope with sudden war emergencies, yet its ready usefulness for daily needs keeps it on the go in any event. Foresighted communities that have purchased this unit are finding that it "pays its way" for sterilizing mains, for treating secondary reservoirs or temporary supplies, and for many other chlorination needs away from the plant . . . needs which may arise in peace or in war. The community is more fully protected in case of floods, droughts and other natural emergencies, as well as from wartime dangers.

Built to take hard service day after day, this W&T equipment can be kept busy without lowering its ability to meet a crisis if need be. And after the war, it will still justify itself with many years of useful peacetime performance. The unit is complete with tools, connecting cocks and hose, and provides self-powered solution feed of chlorine from two 150 lb. cylinders cradled within it. Chlorine can be applied over a wide range of application rates up to 300 lb. per day.

Wallace & Tiernan Representatives will be glad to give you complete details on the W&T Chlorination Trailer, on the new W&T Portable Chlorinator, and other units which fit into the overall picture of wartime water protection, or write for Technical Bulletins.

SA-136

WALLACE & TIERNAN CO., Inc.